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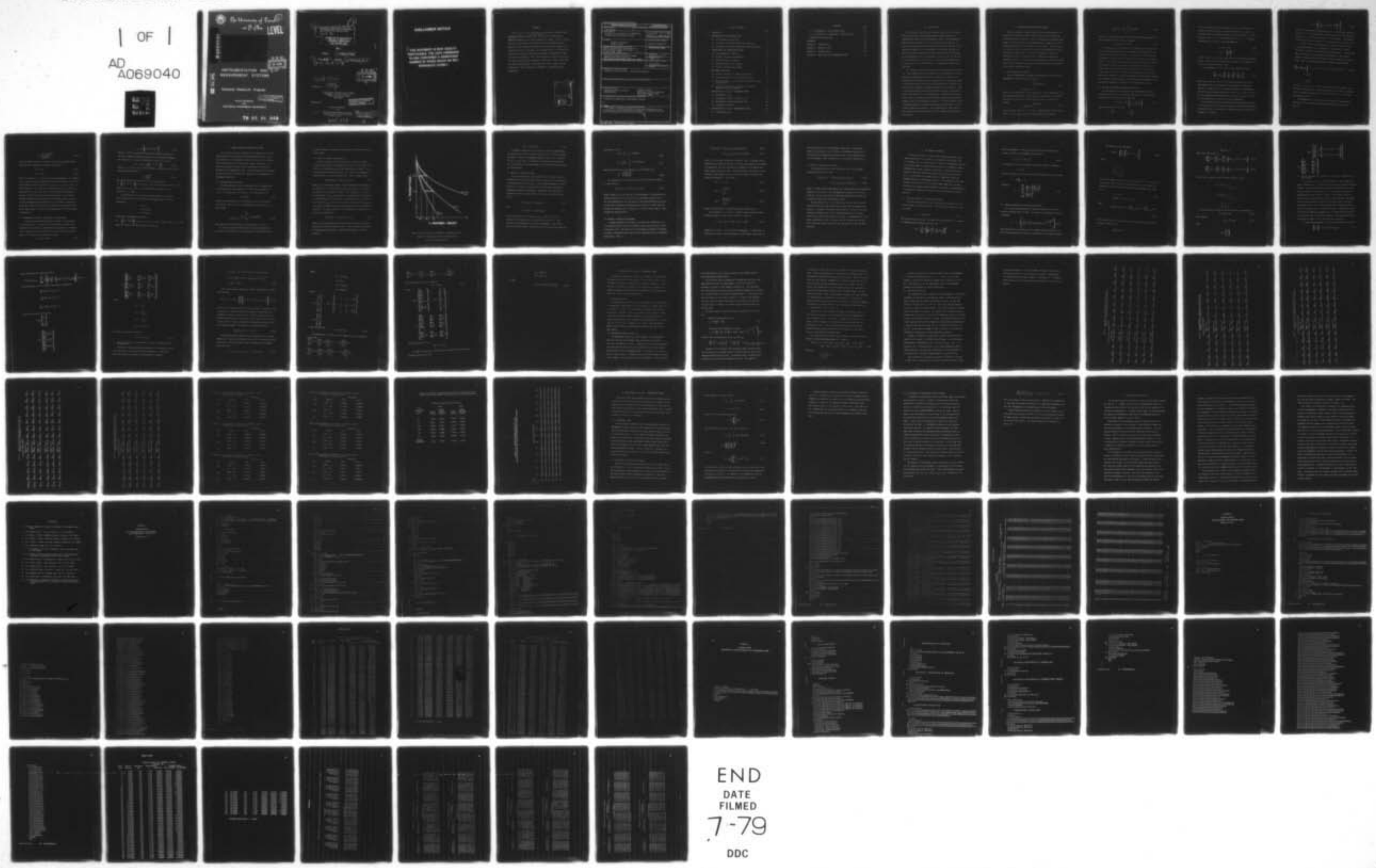

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Atmospheric Transmittance Study with the Meteorological Satellite Technical Area at White Sands Missile Range.

Part I.

METHODS FOR THE CALCULATION OF ATMOSPHERIC TRANSMITTANCE OVER SPECTRAL BANDS.

PART I

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FOREWORD

This is Part I of the final report under Contract DEEA-76-C-0019 entitled Atmospheric Transmittance Study with the Meteorological Satellite Technical Area at White Sands Missile Range. Part II contains the report on the study of the inversion of the radiative transfer equation for the temperature profile as well as for the absorber concentration in the 15μ CO_2 band. Also included there is the method used in this study for the calculation of atmospheric transmittance using line spectral parameters. Part III deals with the study of the effects of clouds on the inversion techniques. Essentially, Part I deals with the study and development of band models for use in connection with techniques for the calculation of atmospheric transmittance along slant-paths.

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A study of transmittance models for molecular absorption in the infrared for use along inhomogeneous atmospheres in connection with the vertical temperature profile retrieval efforts.

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1. INTRODUCTION

The inversion of the radiative transfer equation for the temperature using satellite radiance measurements requires the use of a transmittance function for the atmospheric region. The transmittance function itself, however, if it is to represent accurately the effects of the gaseous absorbers it must be an explicit function of the temperature sought for in the inversion. This implies that the numerical procedures adopted must include the capability for iterating in the computation of the transmittance as close guesses are obtained for the temperature. This would be a relatively simple modification if it were not for the inaccessibility of appropriate transmittance functions.

The principal problems associated with the transmittance function are: long computational times, deviations from measured data, complex analytical representations, inaccurate computational results, and limitations of the conversion from inhomogeneous to homogeneous paths. In this report some of these factors are discussed in connection with the most recent methods and models available in the literature. Based on the work performed with line-by-line data, available from another part of this effort, it is recommended that a transmittance function in the form of a polynomial in the pressure, temperature and absorber amount be used as a homogeneous path model. The model, however, would be developed with the vertical transmittance for each layer in a horizontally stratified atmosphere. The transmittance to each level is then obtained through multiplication of the transmittance through previous layers.

2. TRANSMITTANCE FOR HOMOGENEOUS MEDIA

Infrared radiation passing through a nonscattering medium is absorbed by the molecules along the path in the process of rotational-vibrational energy transitions. The law governing the absorption mechanism is that due to Beer, and its application is dependent on line-broadening mechanisms of the Doppler or Lorentz type. In spite of the fact that the physical processes, as wekl as their mathematical representations are well known, it is still a challenge to arrive a a practical and accurate function for the transmittance through the atmospheric region. In this section a presentation is made of two band models of the polynomial type, which have been found to be of significance value in atmospheric work.

2.1 The transmittance Function

Spectral transmittance through an absorbing gas is given by the monochromatic form of Beer's Law, that is

$$\tau_\nu(P,T,u) = e^{-\int_0^u K_\nu(P,T)\, du'} \tag{2.1}$$

where ν is the frequency, P is the pressure, T is the temperature, u is the absorber amount and K_ν is the absorption coefficient. For homogeneous media P and T do not change along the path, such that (2.1) becomes

$$\tau_\nu(P,T,u) = e^{-K_\nu(P,T)u} \tag{2.2}$$

Over a spectral band $\Delta_\nu = \nu_2 - \nu_1$ use is commonly made of the average value of (2.2), which by the first mean-value theorem becomes

$$\tau_{\Delta\nu}(P,T,u) = \frac{1}{\Delta\nu}\int_{\nu_1}^{\nu_2}\tau_\nu(P,T,u)d\nu \tag{2.3}$$

Since $\tau_{\Delta\nu}$ is the quantity dealt with in the work reported here, further reference will use the short notation

$$\tau_{\Delta\nu}(P,T,u) \equiv \tau(P,T,u) \tag{2.4}$$

The absorption coefficient K_ν in (2.2) depends on the nature of the line-broadening mechanism, on the number and arrangement of the lines and on the type of molecule. Specification of the broadening as being due to either Doppler or Lorentz has allowed for the evaluation of (2.3), with resulting simple analytical expressions. However, the simplicity of the expressions is obtained at the cost of over-simplication of the physical processes involved. These results, or "band models", do not as a general rule represent the actual transmittance to a degree of accuracy high enough to justify their unbiassed use. However, use may be made of their form in the obtainment of more empirically satisfactory functions of the variables P, T and U.

2.2 Polynomial in Weak-and Strong-Line Functions

For the special case of statistically distributed Lorentzian lines over Δ_ν with a Poisson intensity distribution function, Mayer [1] and Goody [2] evaluated (2.3) obtaining

$$\tau(P,T,u) = \exp\left\{-\frac{\beta\psi}{(1+2\psi)^{1/2}}\right\} \tag{2.5}$$

where the variables β and ψ are

$$\beta = \frac{2\pi\alpha_o\alpha}{d} \qquad \psi = \frac{S_o Su}{2\pi\alpha_o\alpha}$$

and α is the mean half width normalized to α_o, d is the mean line spacing, S is the mean line intensity normalized to S_o, and α_o, S_o are their values at standard temperature T_o and pressure P_o. In the weak-line (i.e., $\psi << 1$) and strong-line (i.e., $\psi >> 1$) limiting conditions, (2.5) results in the approximations

$$\tau_w = \exp \{-\beta\psi\} \tag{2.6}$$

$$\tau_s = \exp - \left(\frac{\beta^2\psi}{2}\right)^{1/2} \tag{2.7}$$

in which τ_w and τ_s are called, respectively, the weak-and strong-line models. The pressure and temperature dependence is introduced in the last three equations through and S.

A re-arrangement of (2.5) leads to the geometrical form

$$\left(\frac{-1}{\ell n\ \tau\ (P,T,u)}\right)^2 = \left(\frac{-1}{\ell n\ \tau_w}\right)^2 + \left(\frac{-1}{\ell n\ \tau_s}\right)^2 \tag{2.8}$$

which states that the inverse of the natural logarithm of the two approximations are in quadrature with the complete transmittance function. If this result is considered universal for transmittance, then (2.8) may be generalized with the choice of a τ_s which is valid also for regularly distributed lines. The choice of τ_w as in (2.6) is a valid selection for any type of line arrangements.

Of the strong-line models available the most adaptable to (2.8) is the one due to Kine [3], which represents a continuous distribution of Lorentzian lines from regular to random through the variation of a parameter. Accordingly,

$$\tau_s = 1-G\left\{n, \left[n\,\Gamma(n)\,\left(\frac{2}{\pi}\beta^2\psi\right)^{1/2}\right]^{1/n}\right\} \tag{2.9}$$

where G is the incomplete gamma function, Γ is the regular gamma function, and n is the parameter that specifies the type of line distribution (e.g. n = 0.5 for regular and n = 1.0 for random). The generalization of the Mayer-Goody model in this manner is due to Zachor [4,5].

In spite of the above-mentioned broad interpretations of such classical band models, their adaptation to measurements is always restricted by hidden factors affecting the measurements. The deviation from the idealism of the mathematical formulation of the physical process of absorption may be accounted for by the addition of terms in (2.8). Thus, a polynomial model may be proposed in the form [6].

$$\left(\frac{-1}{\ell n\ \tau\ (P,T,u)}\right)^2 = C_1 x^2 + C_2 y^2 + C_3 xy + C_4 x^2 y + C_5 xy^2 + \ldots \tag{2.10}$$

$$x = \frac{-1}{\ell n\ \tau_\omega}$$

$$y = \frac{-1}{\ell n\ \tau_s}$$

and the C_i's (i = 1,. . ., N) are determined from least-squares curve-fitting to measured data. The N-term polynomial in (2.10) is described by N + 3 spectral parameters, two of which arise from τ_s in (2.9) and one from τ_w in (2.6).

The dependence of τ on P,T and u may be explicitly made apparent with the use of the normalized Lorentzian half-width α in β and ψ, that is

$$\alpha = \left(\frac{P}{P_o}\right)\left(\frac{T_o}{T}\right)^{1/2} \tag{2.11}$$

Also, the model variables in (2.6) and (2.9) may be separated from their spectral dependence by expanding in the form

$$\beta\psi = k\ Su \tag{2.12}$$

$$\beta^2\psi = C\ S\alpha u \tag{2.13}$$

where $k = S_o/d$ and $C = 2\ d_oS_o/d^2$ are spectral parameters. The complete set of spectral parameters describing an N-term expansion of the polynomial model in (2.10) consists of C_1, C_2, C_3,..., C_N, k, n and C. In the development of the model with transmittance data, k, n and C are determined first and, then, the C_i's are determined *simultaneously*. Details of the process will be given in Section 4 of this report. Although the model has been derived for homogeneous paths, it may be used for inhomogeneous paths with the use of variables equivalent to Su and Sαu. These may be called the weak-line and strong-line variables, respectively. Details on these equivalences will be discussed in Section 6.2.

2.3 Polynomial in Pressure, Temperature & Concentration

A totally different approach may be followed in the obtainment of a polynomial for τ in terms of functions explicitly showing the dependence on the pressure, temperature and gas amount (or concentration). With the use of (2.12) and (2.13), the weak-and strong-line models in (2.6) and (2.7), respectively become

$$\tau_w = \exp\ \{-k\ Su\} \tag{2.14}$$

$$\tau_s = \exp\left\{-k' S^{1/2} \alpha^{1/2} u^{1/2}\right\} \tag{2.15}$$

where $k' = \sqrt{C/2}$. An inspection of the powers associated with the variables in these two limiting equations for transmittance suggests the assumption of a general transmittance equation of the form

$$\tau\ (P,\ T,\ u) = \exp\left\{-k'' \ S^a \ \alpha^b \ u^c\right\} \tag{2.16}$$

where k'', a, b, and c are spectral constants. Replacing α with (2.11), using the approximation [7]

$$S = \left(\frac{T}{T_o}\right)^d \tag{2.17}$$

and taking the natural logarithm of (2.16) twice leads to

$$\ell n \left\{-\ell n\ \tau\ (P,\ T,\ u)\right\} = a_1 + a_2\ \ell n\ u + a_3\ \ell n\ (P/P_o) + a_4\ \ell n\ (T/T_o) \tag{2.18}$$

where d, a_1, a_2, a_3, and a_4 are constants related simply to the earlier k'', a, b and c.

The polynomial in (2.18) may be further expanded to allow for better flexibility in curve-fitting to experimental data. With the definitions

$$x = \ell n\ u$$

$$y = \ell n\ (P/P_o)$$

$$z = \ell n\ (T/T_o)$$

(2.18) may be expanded into the form

$$\ell n \left\{-\ell n\ \tau\ (P,T,u)\right\} = a_1 + a_2 x + a_3 y + a_4 z + a_5 xy + a_6 yz + a_7 zx + \ldots \tag{2.19}$$

which is a form of the model proposed by Smith [8].

3. TRANSMITTANCE FOR INHOMOGENEOUS MEDIA

In the previous section a discussion was presented of two polynomial models for transmittance through homogeneous media. Since the atmosphere is an inhomogeneous media it is necessary to somehow modify the previous theory to make the results applicable. Only under very special and impracticable assumptions can a model be derived for the inhomogeneous case. Several procedures are discussed in this section for effecting the transition from inhomogeneous to homogeneous conditions.

3.1 The Transmittance Function

For paths through the Earth's atmosphere use is commonly made by the "hydrostatic approximation" to convert the integration in (2.1) to an integration over pressure. Such approximation is

$$du = \frac{M}{g}\, dP \tag{3.1}$$

where M is the mixing ratio of the absorber and g is the gravity acceleration. Beer's law for an inhomogeneous path from P_1 to P_2 then becomes

$$\tau_\nu(P,T,u) = e^{-\frac{1}{g}\int_{P_1}^{P_2} K_\nu\,(P,T)M(P)dP} \tag{3.2}$$

which must also be averaged over a spectral band as in (2.3).

In view of essential difficulties in the exact evaluation of (3.2) for a path along which P_2 is significantly different from P_1,

use must be made of the knowledge gain from its evaluation for homogeneous paths.

3.2 Method of Weinreb and Neuendorffer

A given atmosphere may be described by a family of N curves-of-growth representing the transmittance along a vertical path. Each curve is for constant presure P_i and temperature T_i, where $i = 1, \ldots, N$, as depicted qualitatively in Fig. 3.1. Since the transmittance along the path to a given pressure level i must be unique, then

$$\tau(P_i, T_i, u'_{i-1}) = \tau(P_{i-1}, T_{i-1}, u_{i-1}) \tag{3.3}$$

where u_{i-1} is the absorber amount contained between the atmospheric top and level i-1 at conditions of level i-1, and u'_{i-1} is the same variable but at conditions of level i. The amount u'_{i-1} is said to be "equivalent" to u'_{i-1} in the sense of satisfying (3.3). According to the method proposed by Weinreb and Neuendorffer [9] a solution is first found for u'_{i-1} from (3.3) with both a knowledge of $\tau(P_{i-1}, T_{i-1}, u_{i-1})$, and an available band model for homogeneous paths evaluated at P_i and T_i. It follows then that the transmittance to the next pressure level is obtained as

$$\tau(P_i, T_i, u_i) = \tau(P_i, T_i\ u'_{i-1} + \Delta u_i) \tag{3.4}$$

where Δu_i is the incremental absorber amount contained in the path length ΔZ_i between the pressure levels. This incremental gas amount is computed with a knowledge of the absorber density ρ with the equation

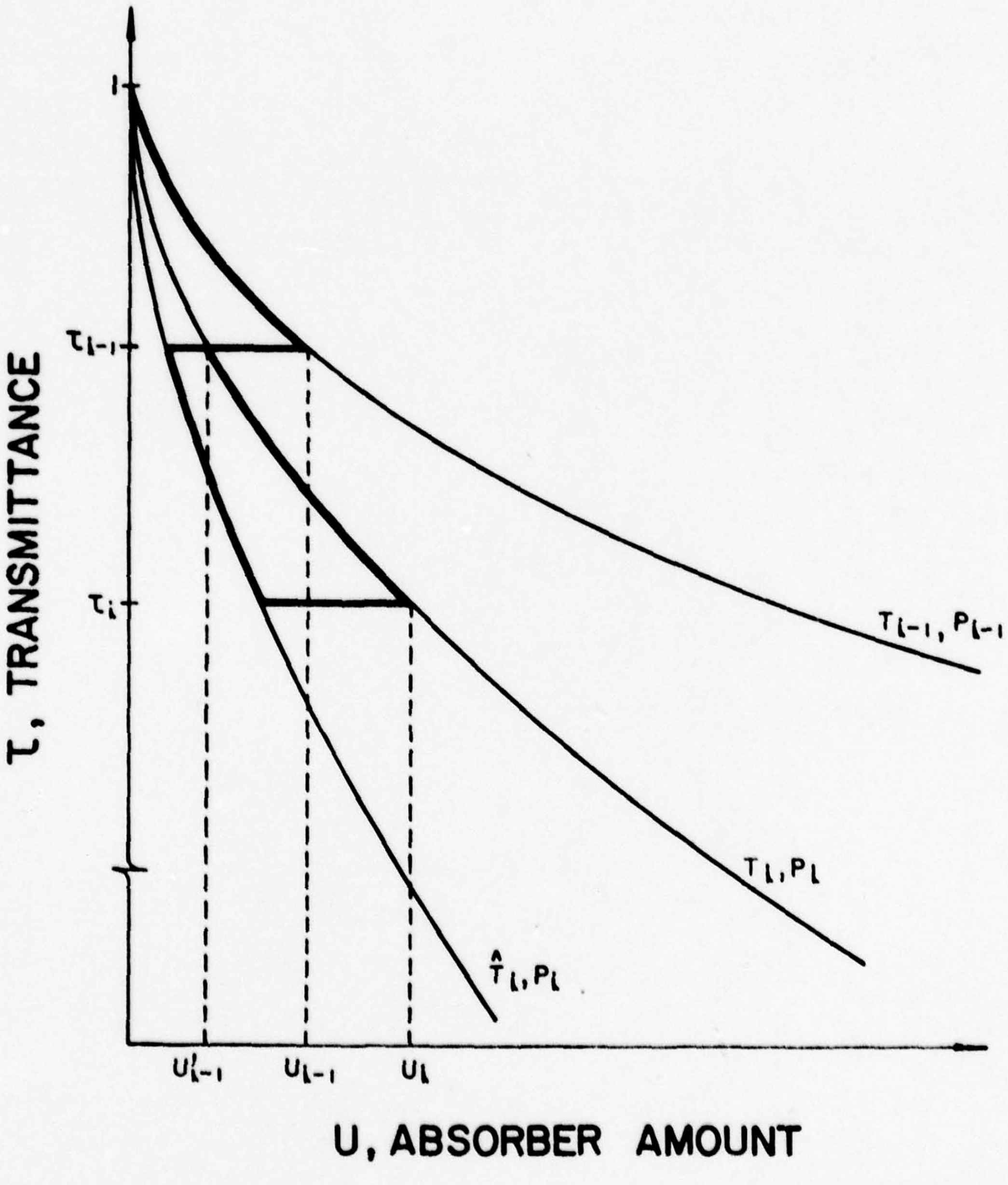

Fig. 3.1. Representation of atmospheric transmittance by a family of transmittance curves-of-growth (after Weinreb and Neuendorffer)

$$\Delta u_i = \rho(T_i, P_i)\Delta Z_i \tag{3.5}$$

Although in principle (3.3) is exact for general transmittance, its application to actual cases involves the use of both an existing band model $\tau(P,T,u)$ for homogeneous paths, as well as of a solution for u'_{i-1} at each level. In addition to introducting inaccuracies, these steps impose additional demands on the computational algorithm for transmittance.

3.3 Method of Curtis and Godson

A classical and widely used alternative to the above method is that which uses the Curtis-Godson [10,11] relations in the computation of the equivalent gas amount u'_{i-1}. This method establishes two equations for (3.3) which are exact only in the limiting conditions of weak-and strong-line transmittance. From these follow equivalent relations for the gas amount and as well as for the level pressure. That is

$$\tau(P_i, T_i, u_i) = \tau_\omega(T_i, u'_{i-1}) \tag{3.6}$$

and

$$\tau(P_i, T_i, u_i) = \tau_s(P'_i, T_i, u'_{i-1}) \tag{3.7}$$

which lead directly to a solution for u'_{i-1} from (3.6), and to a solution for the equivalent level pressure P'_i from (3.7). Such solutions are independent of the type of band model. They follow directly from the integral form of Beer's law (2.1) and the Lorentzian

half-width (2.11) as

$$u'_{i-1} = \frac{1}{S_i} \int S(z)du(z) \qquad (3.8)$$

$$\alpha'_i = \frac{1}{S_i u'_{i-1}} \int S(z)\alpha(z)du(z) \qquad (3.9)$$

where the integration is carried over the path length, and

$$\alpha'_i = \left(\frac{P'_i}{P_o}\right)\left(\frac{T_o}{T_i}\right)^{1/2} \qquad (3.10)$$

The transmittance to the next pressure level follows according to this method as

$$\tau(P_i,T_i,u_i) = \tau(P'_i,T_i,u'_{i-1} + \Delta u_i) \qquad (3.11)$$

Briefly stated, (3.11) is based on the determination of an equivalent gas amount following a curve-of-growth at an equivalent pressure, but at the same temperature as that provided by the Weinreb-Neuendorffer method. A little more conceptual development may be used [12] to show that the methods are identical when $\tau(P_i,T_i,u_i)$ is of either purely weak or purely strong-line characteristics.

3.4 Method of McMillin and Fleming

A recent approach to the problem by McMillin and Fleming [13] led to the separation of (3.4) into a product of two functions, one of which is given by (3.3). The other is a four-parameter polynomial f expressed in terms of temperature differences within isothermal layers of uniformly-mixed gases. That is

$$\tau(P_i,T_i,u_i) = \tau(P_i,T_i,u'_{i-1})f(\Delta T_i,\Delta T'_i,\Delta T''_i) \qquad (3.12)$$

$$= \tau(P_{i-1},T_{i-1},u_{i-1})f(\Delta T_i,\Delta T'_i,\Delta T''_i) \qquad (3.13)$$

where ΔT_i is the level temperature difference from a reference average temperature $\overline{T}_i$, while $\Delta T'_i$ and $\Delta T''_i$ are these same temperature differences but weighted by the level pressure and averaged over the entire atmospheric region above the level. Since they follow from the use of the equivalent mass concept, they may as well be called "equivalent temperature differences". Specifically,

$$\Delta T_i = T_i - \overline{T}_i \qquad (3.14)$$

$$\Delta T'_i = \frac{\int \Delta T(P)dP}{\int dP} \qquad (3.15)$$

$$\Delta T''_i = \frac{\int P\Delta T(P)dP}{\int PdP} \qquad (3.16)$$

where the integration is carried along the path ending at P_i.

The polynomial f in (3.13) is a function representing the transmittance through the layer, and is given for a layer as

$$f = b_1 + b_2\Delta T + b_3\Delta T^2 + b_4\Delta T' + b_5\Delta T'' \qquad (3.17)$$

where the b_j's ($j=1,\ldots,5$) are spectral parameters. In particular, b_1 represent the ratio of the transmittance to the bottom of the layer to

the value at the top for the reference temperature. The original intent in arriving at f was to allow for a convenient procedure for calculating the transmittance through a layer at any temperature $\overline{T}_i$, with a knowledge of the transmittance at a reference temperature T_i.

3.5 Method of Transmittance Product

The separation of (3.4) into the product form (3.12) suggests another separation in the form

$$\tau(P_i, T_i, u_i) = \tau(P_i, T_i, u_{i-1}^{*})\Delta\tau(P_i, T_i, \Delta u_i) \quad (3.18)$$

$$= \tau(P_{i-1}, T_{i-1}, u_{i-1})\Delta\tau(P_i, T_i, \Delta u_i) \quad (3.19)$$

where $\Delta\tau$ is the transmittance through Δu_i. Even though the approximations inherent in (3.19) are of the same magnitude as those in (3.12), the function $\Delta\tau$ is not restricted to temperature dependence alone, and may be used for nonuniformly-mixed gases as well.

Further attractiveness of (3.19) lies in the fact that $\Delta\tau$ may be represented with any general band model, which shows the explicit dependence on pressure, temperature and gas amount. One set of spectral parameters describing such model could be developed for the entire atmosphere for each spectral band of interest. An examination of (3.19) shows, additionally, that it is exact for the monochromatic case and that it does not require the use of any equivalences in the variables involved.

4. BAND MODEL DEVELOPMENTS

By model development is usually meant the determination of the spectral parameters of the model using measured transmittance data. In the absence of a sufficient amount of data from experimental analyses use is mostly made of line-by-line calculations for theoretical paths resembling the actual atmospheric situations. By line-by-line calculations is meant the evaluation of Beer's law in the form of either (2.1) or (2.2) using the parameters of each significant line, and assuming some type of broadening function. This procedure is discussed in detail in the second part of the final report under this contract. In this section a least-squares technique is applied to the determination of the spectral parameters for the two polynomial models presented in Section 2.

4.1 Spectral Parameters for Weak-Line Function

The weak-line approximation for the Mayer-Goody model, as well as for most models, was given by (2.6). In terms of the variable in (2.12) it becomes

$$\tau_w = \exp\{-kSu\} \qquad (4.1)$$

The curve fitting technique to be used in the determination of k consists of minimizing the difference function d as

$$d(k) = \sum_{i=1}^{N} W_i \left\{ \left(\frac{-1}{\ln \tau_i} \right)^2 - \left(\frac{-1}{\ln \tau_{w,i}} \right)^2 \right\}^2 \qquad (4.2)$$

where the summation is over all levels for which data exists on P_i, T_i and τ_i, and W_i is the weighting function [14]

$$W_i(\tau_i) = \tau_i^2 \, (\ell n \, \tau_i)^6 \tag{4.3}$$

For convenience in the minimization process the change of constants

$$B = 1/k^2$$

may be introduced so that the least-squares derivative of (4.2) becomes

$$\frac{\partial d(B)}{\partial B} = 0$$

leading to

$$B = \frac{\displaystyle\sum_{i=1}^{N} W_i \left(\frac{-1}{\ell n \, \tau_i}\right)^2 \left(\frac{1}{S_i u_i}\right)^2}{\displaystyle\sum_{i=1}^{N} W_i \left(\frac{1}{S_i u_i}\right)^4} \tag{4.4}$$

4.2 Spectral Parameter for Strong-Line Function

The strong-line approximation of greatest versatility is the one given by King and stated in (2.9). In terms of the variable in (2.13), it becomes

$$\tau_s = 1 - G\left\{ n, \left[n\Gamma(n) \left[\frac{2}{\pi} \, CS(P/P_o)(T_o/T)^{1/2} \right]^{1/2} \right]^{1/n} \right\} \tag{4.5}$$

Since the spectral parameters n, and C appear within the function G in (4.5), their determination requires a non-linear curve-fitting procedure.

The quantity to be minimized is

$$d(n,C) = \sum_{i=1}^{N} W_i \left\{ \ell n\, \alpha_i - \ell n\, \alpha_{s,i} \right\}^2 \tag{4.6}$$

where

$$W_i = 1$$
$$\alpha_i = 1 - \tau_i$$
$$\alpha_{s,i} = 1 - \tau_{s,i}$$
$$= G(n,C)$$

It is first assumed in (4.6) that an assumed point n', C' is very close to the point which yields the computed minimum of d and, then, d_i is expanded in a two term Taylor series about the assumed point. That is, if

$$B = \ell n\, C \tag{4.7}$$
$$d_i(n,B) = \ell n\, \alpha_i - \ell n\, \alpha_{s,i}$$

then

$$d_i(n,B) = d_i(n',B') + \left.\frac{\partial d_i}{\partial n}\right|_{n',B'} (n-n') + \left.\frac{\partial d_i}{\partial B}\right|_{n',B'} (B-B') \tag{4.8}$$

After substitution of (4.8) into (4.6), the minimum point is obtained through the derivatives

$$\frac{\partial d}{\partial n}(n,B) = 0$$

$$\frac{\partial J}{\partial B}(n,B) = 0$$

which yuild the linear set

$$\Delta B \sum_i x_i^2 + \Delta n \sum_i x_i y_i = \sum_i x_i \left\{ \ln \alpha_{s,i}\,(n',B') - \ln \alpha_i \right\} \qquad (4.9)$$

$$\Delta B \sum_i x_i y_i + \Delta n \sum_i y_i^2 = \sum_i y_i \left\{ \ln \alpha_{s,i}\,(n',B') - \ln \alpha_i \right\} \qquad (4.10)$$

In this set of equations, the following notation is used

$$x_i = \frac{\partial}{\partial n} \ln \alpha_{s,i} \Big|_{n',\,B'}$$

$$y_i = \frac{\partial}{\partial n} \ln \alpha_{s,i} \Big|_{n',\,B'}$$

$$\Delta n = n - n'$$

$$\Delta B = B - B'$$

In matrix form (4.9) and (4.10) may be written conveniently as

$$[P\,]\,[A] = [D] \qquad (4.11)$$

with solution

$$[A] = [P^{-1}]\,[D] \qquad (4.12)$$

where

$$[A] = \begin{bmatrix} \Delta B \\ \Delta n \end{bmatrix}$$

$$[D] = \begin{bmatrix} \sum_i x_i \left\{ \ln \alpha_{s,i} (n',B') - \ln\alpha_i \right\} \\ \sum_i y_i \left\{ \ln \alpha_{s,i} (n',B') - \ln\alpha_i \right\} \end{bmatrix}$$

$$[P] = \begin{bmatrix} \sum_i x_i^2 & \sum_i x_i y_i \\ \sum x_i y_i & \sum y_i^2 \end{bmatrix}$$

4.3 Spectral Parameters for Polynomial in Pressure, Temperature and Concentration

In a previous section a polynomial model was derived which expressed transmittance as a function of the weak-and strong-line approximations. Although the model as given by (2.10) allows for an expansion in products of functions of τ_w, τ_s, it is seldom advisable to include more than the first three terms. This premise is based on the fact that for purely weak-or purely strong-line data, the models for these limits normally curve-fit sufficiently well to the data. The problem lies in the region in between these limiting condition, since the available data τ is more than likely an inseparable mixture of weak-and strong-line transmittances. Any additional term beyond the third will tend to place undue weights on the limiting functions, decreasing the effect of the "interpolating" third term.

In a three-term expansion, (2.10) may be re-written in the form

$$\left(\frac{-1}{\ln \tau}\right)^2 = B_w x^2 + B_s y^2 + B_{w,s} xy \qquad (4.13)$$

which yields the least-squares relation

$$d\,(B_w,\ B_s,\ B_{w,s}) = \sum_{i=1}^{N} W_i \left\{ \left(\frac{-1}{\ln \tau_i} \right)^2 - \left(B_w x_i^2 + B_s y_i^2 + B_{w,s} x_i y_i \right) \right\}^2 \quad (4.14)$$

The minimization of (4.14) based on the partial derivatives

$$\frac{\partial}{\partial B_w} d(B_w,\ B_s,\ B_{w,s}) = 0$$

$$\frac{\partial}{\partial B_s} d(B_w,\ B_s,\ B_{w,s}) = 0$$

$$\frac{\partial}{\partial B_{w,s}} d(B_w,\ B_s,\ B_{w,s}) = 0$$

results in the matrix formulation

$$[A] = \begin{bmatrix} B_w \\ B_s \\ B_{w,s} \end{bmatrix}$$

$$[D] = \begin{bmatrix} \sum_i W_i x_i^2\ F_i^2 \\ \sum_i W_i y_i^2\ F_i^2 \\ \sum_i W_i x_i y_i F_i^2 \end{bmatrix}$$

$$[P] = \begin{bmatrix} \sum_i W_i x_i^4 & \sum_i W_i x_i^2 y_i^2 & \sum_i W_i x_i^3 y_i \\ \sum_i W_i x_i^2 y_i^2 & \sum_i W_i y_i^4 & \sum_i W_i x_i y_i^3 \\ \sum_i W_i x_i^3 y_i & \sum_i W_i x_i y_i^3 & \sum_i x_i^2 y_i^2 \end{bmatrix}$$

where

$$F_i = -\frac{1}{\ln\tau_i}$$

$$x_i = -\frac{1}{\ln\tau_{w,i}}$$

$$y_i = -\frac{1}{\ln\tau_{s,i}}$$

$$W_i = \tau_i^2 \, (\ln\tau_i)^6$$

As before, the solution follows as

$$[A] = [P^{-1}] \; [D] \tag{4.15}$$

4.4 Spectral Parameters for Polynomial in Pressure, Temperature and Concentration

The model of Smith expresses transmittance as a Polynomial function of the gas amount, the pressure and the temperature. In its most useful form [9] the Polynomial is expanded into 14 terms as

$$\ln(-\ln\tau) = a_1 + a_2 x + a_3 y + a_4 z + a_5\, xy + a_6 xz$$

$$+ a_7 x^2 + a_8 x^2 z + a_9 yz + a_{10} x^3 + a_{11} xz^2 + a_{12} z^2$$

$$+ a_{13} xyz + a_{14} yx^2 \qquad (4.16)$$

For a least-squares analysis of (4.16) a minimization is made of the difference

$$d(a_j,\ j=1,\ldots,14) = \sum_{i=1}^{N} \left\{ \ln(-\ln\tau) - g(a_j,\ j=1,\ldots,14) \right\}^2 \qquad (4.17)$$

where g is the right-hand side of (4.16). Because of the difficulties in arriving at a weighting function of physical significance, no weighting function is used in (4.17). In view of the sizes of the matrices associated with a solution of (4.17), they are not presented in this section. They are included in the Appendix with the associated computer programs. The matrices follow the derivatives

$$\frac{\partial}{\partial a_j} d(a_j,\ j=1,\ldots,14) = 0 \qquad (4.18)$$

Although the matrix solution (4.12) is applicable to the least-squares set of equations obtainable from (4.17), a different approach may be taken. For each pressure level an equation may be written having the form

$$t_i = a_1 + a_2\, x_i + a_3\, y_i + \ldots + a_{14}\, y_i x_i^2 \qquad (4.19)$$

where

$$t_i = \ln(-\ln \tau_i)$$

$$x_i = \ln u_i$$

$$y_i = \ln(P_i/P_o)$$

$$z_i = \ln(T_i/T_o)$$

Define

$$[Y] = \begin{bmatrix} t_1 \\ \\ t_2 \\ \vdots \\ t_N \end{bmatrix} , \quad [B] = \begin{bmatrix} 1 & x_1 & y_1 & \cdots & y_1 x_1^2 \\ \\ 1 & x_2 & y_2 & \cdots & y_2 x_2^2 \\ \vdots & \vdots & \vdots & & \vdots \\ 1 & x_N & y_N & & y_N x_N^2 \end{bmatrix}$$

$$[A] = \begin{bmatrix} a_1 \\ \vdots \\ \\ a_{14} \end{bmatrix}$$

so that we may write

$$[Y] = [B]\,[A] \tag{4.20}$$

The application of (4.18) to (4.17) yields a set of 14 equations of the form

$$\sum_i t_i = a_1 \sum_i 1 + a_2 \sum_i x_i + \ldots + a_{14} \sum_i x_i^2\, y_i$$

$$\sum_i t_i x_i = a_1 \sum_i x_i + a_2 \sum_i x_i^2 + \ldots + a_{14} \sum_i x_i^3\, y_i$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad\qquad \vdots$$

$$\sum_i t_i x_i^2 y_i = a_1 \sum_i x_i^2 y_i + a_2 \sum_i x_i^4 y_i + \ldots + a_{14} \sum_i x_i^4 y_i^2$$

which using matrices may be written as

$$[S] = [U]\,[V] \tag{4.21}$$

where

$$[S] = \begin{bmatrix} \sum_i t_i \\ \sum_i t_i x_i \\ \vdots \\ \sum_i t_i x_i^2 y_i \end{bmatrix}, \quad [V] = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_{14} \end{bmatrix}$$

$$[U] = \begin{bmatrix} \sum_i 1 & \sum_i x_i & \cdots \sum_i x_i^2 y_i \\ \sum_i x_i & \sum_i x_i^2 & \cdots \sum_i x_i^3 y_i \\ \vdots & & \\ \sum_i x_i^2 y_i & \sum_i x_i^4 y_i & \cdots \sum_i x_i^4 y_i^2 \end{bmatrix}$$

The solution of (4.20) is

$$[V] = [U]^{-1}\,[S]$$

To find the solution for [V] by matrix operation on the previously defined matrices, note that

$$[U] = [B^T]\ [B]$$

$$[S] = [B^T]\ [Y]$$

so that

$$[V] = ([B^T]\ [B])^{-1}\ [B^T]\ [Y] \qquad (4.22)$$

5. APPLICATION TO 15μm CO_2: HOMOGENEOUS PATHS

In order to evaluate the validity and usefulness of the formulation presented in the earlier sections of this report, several of the procedures and models were developed for computer solutions. In this section a discussion is presented of the equations, procedures and computer programs associated with the developments of the homogeneous-path case for the 15μm CO_2 spectral band.

5.1 Transmittance Data

The transmittance data used in the development of the band models for homogeneous paths consisted of 200 values in the ragnes from 0.005 to 0.5 and 0.5 to 50 atm. cm. at Standard Temperature and Pressure. The data were available for all six channels of the vertical temperature profile retrieval (VTPR) experiment in the 15μm CO_2 band. The center frequencies for these channels are approximately 667, 677, 694, 708, 725, and 747 cm^{-1}. Details of the line-by -line calculational methods used to arrive at these data are given in part two of this final report.

5.2 Development of Model in Eq. 4.13

The band models chosen for curve-fitting to the transmittance data were those of the polynomial-type as proposed by Pierluissi (Eq. 4.13) and Smith (Eq. 4.16). In particular, 4.13 had been proposed and developed some time prior to the period covered by this contract [15] and called the Five-Parameter model. The Theory of its development is repeated here for convenience and, at the same time, some beneficial changes to the original version are introduced. The innovations

are incorporated into the original program called IRABSMD, and the resulting program renamed EIKCIM.

In the earlier work the exponential limiting function for τ_w had been substituted into the comple model, in such a way that its parameter K was part of the quadratic parameter B_w. This precluded the curve-fitting of weak-and strong-line models independently, followed by a curved-fitting to the general quadratic model. In principle, this latter procedure is more nearly correct or, at least, more consistent. Initially, only the strong-line model was curve-fitted individually. The following is a summary of the model version developed under the present effort.

The model forms developed following the procedures of Section 4 are:

Weak-Line (Determination of k)

$$\tau_w = \exp\left\{-k\ S\ u\right\} \tag{4.1}$$

Strong-Line (Determination of n and C)

$$\tau_s = 1-G\left\{n,\ \left[n^{\Gamma}(n)\left[\frac{2}{\pi}\ CS\ (P/P_o)\ (T_o/T)^{1/2}\right]^{1/2}\right]^{1/n}\right\} \tag{4.5}$$

Complete Model (Determination of B_w, B_s, and B_{ws})

$$\left(\frac{-1}{\ln \tau}\right)^2 = B_w\left(\frac{-1}{\ln \tau_w}\right)^2 + B_s\left(\frac{-1}{\ln \tau_s}\right)^2 + B_{ws}\left(\frac{1}{\ln \tau_s\ \ln \tau_s}\right) \tag{4.13}$$

Because of the presence of the incomplete gamma function the model has proven to be somewhat harder to develop than the other polynomial-type model discussed below. The problem arises in reaching convengence for the strong-line parameters n and C. This model is

non-linear in M and C and had to be linearized for its present application. Thus, the determination of these spectral parameters need to be determined through iterations from an initial guess. This is a troublesome and time-consuming process which is required every time that the data is changed and new parameters need to be developed. For this reason, the presentation of its development here is not intended for use by White Sands Missile Range in their VTPR experiment. For that purpose the model of Smith is recommended, together with some technique for inhomogeneous-to-homogeneous path conversion. The model was, however, developed and the results for channel 1 is included in Appendix A together with program EIKCIM. The results have not been optimized.

5.3 Development of Model in Eq. 4.16

The model of Smith, discussed in detail in Sections 3 and 4 of this report, was selected for development using the homogeneous-path data of Sub-section 5.1. This model is easier to use because it is simply a linear combination of logarithmic functions involving the variables u, P and T. Calculations using the developed model are equally fast and accurate since the process consists of the evaluation of a polynomial of the third power.

The form of the Smith's model used is given by 4.16 with the terms propsed by Weinreb and Neuendorffer [9], that is

$$\begin{aligned} n(-\ln t) = {} & a_1 + a_2x + a_3y + a_4z + a_5xy + a_6xz + a_7x^2 + a_8x^2z \\ & a_9yz + a_{10}x^3 + a_{11}xz^2 + a_{12}z^2 + a_{13}xyz + a_{14}\, yx^2 \end{aligned} \tag{4.16}$$

where now

$$x = 0.1 \ln u$$
$$y = \ln P$$
$$z = \ln T$$

Equation 4.16 was used in program EIGGAM 2 for the determination of the spectral parameters a_i ($i = 1, \ldots, 14$). A copy of the program is included in Appendix B together with a sample of the output. The results for the six VTPR channel and for all principal absorbers are presented in the next Sub-section.

5.4 Tabulation of Results

The transmittance data available for the development of the Smith's band model for CO_2 and H_2O contained two ranges in the gas amounts, namely: 100 points for amounts from 0.005 to 0.5 atm. cm. and 100 points for amounts from 0.5 to 50 atm. This break down was selected in order to cover the entire portion of the curve-of-growth of interest with a high degree of accuracy. The region of the curve-of-growth was decided upon on the basis of available transmittance data for a Standard vertical profile from satellite to ground. The model developed for the latter range would be used in atmospheric transmittance calculations to a larger extent that the former. For O_3 the range from 0.005 to 0.5 atm. cm. in more than sufficient in order to be able to calculate the atmospheric transmittance for any reasonable O_3 profile.

Tables 5.1 through 5.5 contain the 14 Smith's polynomial parameters for all ranges, all channels and all gases. For calculations, these should be substituted in Eq. 4.16 with u in atm. cm., P in millibars and T in degrees Kelvin. For a given homogenoeus path at these conditions, the resultant transmittance will be the product of the individually calculated transmittances for CO_2, H_2O and O_3.

Once determined, the spectral parameters of Tables 5.1 through 5.5 were used to recalculate the original transmittance data in order

to have some measure of their correctness. The mean of the absolute differences between the calculated and the original transmittances were evaluated and tabulated in Tables 5.6 through 5.11. Included in these tables are also the peak deviations obtained for all cases considered.

TABLE 5.1 SMITH POLYNOMIAL COEFFICIENTS AT STP FOR VTPR CHANNELS: CO_2 IN THE RANGE 0.005 TO 0.5 ATM. CM.

SMITH POLYNOMIAL COEFFICIENTS

CHANNEL NO. 1

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.255+00	-.103+01	.614-01	.201+00	-.327-01	.299-01	-.558-01	.125-01	-.205-01	.103-01	.295-01	.566-02	.184-01	.482-02

CHANNEL NO. 2

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.615+00	-.183+01	.952-01	.244+00	-.655-01	.310-02	-.983-01	.253-01	-.271-01	-.133-02	.420-01	-.395-02	.392-01	-.137-01

CHANNEL NO. 3

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.313+01	.587+01	-.423+00	-.819+00	-.119+00	.573+00	.131+00	-.161+00	.127+00	-.450-02	-.762-01	-.344-01	-.135+00	.101+00

CHANNEL NO. 4

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.301+01	.434+01	-.447+00	-.817+00	-.214+00	.619+00	.271+00	-.140+00	.119+00	-.258-02	-.296-01	-.482-01	-.117+00	.679-01

CHANNEL NO. 5

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.828+00	.103+01	-.133+00	-.432+00	-.115+00	.139+00	.650-01	-.333-01	.342-01	-.604-02	.353-01	-.276-01	-.367-01	.704-02

CHANNEL NO. 6

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.115+01	.490+00	-.206+00	-.778+00	-.209+00	.486+00	-.702-01	-.718-01	.639-01	-.533-03	.155-01	-.431-01	-.331-01	.637-01

TABLE 5.2 SMITH POLYNOMIAL COEFFICIENTS AT STP FOR VTPR CHANNELS: CO_2 IN THE RANGE 0.5 TO 50 ATM. CM.

POLYNOMIAL COEFFICIENTS

CHANNEL NO. 1

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.145-02	.432+00	.182-01	.129+00	-.185-01	.966-02	.240+00	.229-02	-.724-02	.496-02	.273-02	.325-02	.207-02	-.333-01

CHANNEL NO. 2

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.394+00	-.200-01	-.981-01	.161+00	.235+00	-.483-01	-.186+00	-.447-01	.606-02	.448-02	-.235-01	-.203-01	.234-02	.646-01

CHANNEL NO. 3

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.478-01	-.653+00	-.326-02	-.142+00	-.304-02	.126+00	.382-02	.222-01	.152-01	-.354-02	.698-02	-.109-01	.119-01	-.172-01

CHANNEL NO. 4

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.800-03	.291+00	-.443-01	-.240+00	-.307-01	.932-01	.720-01	.839-03	.210-01	.754-03	.163-02	-.241-01	.140-01	-.157-01

CHANNEL NO. 5

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.269+00	.999+00	-.533-01	-.159+00	-.134+00	-.326-01	.171+00	-.243-01	.146-01	.540-02	-.263-02	-.360-01	.219-01	-.960-02

CHANNEL NO. 6

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.668+00	.289+01	-.105+00	-.673-02	-.245+00	-.185+00	.446+00	-.744-01	-.763-03	-.173-02	-.904-02	-.646-01	.284-01	-.979-02

TABLE 5.3 SMITH POLYNOMIAL COEFFICIENTS AT STP FOR VTPR
CHANNELS: H_2O IN THE RANGE 0.005 TO 0.5 ATM. CM.

POLYNOMIAL COEFFICIENTS

CHANNEL NO. 1

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.609-01	-.745+00	-.177-01	.466-01	-.126+00	.132+00	-.556-01	-.117-01	-.763-02	.712-02	.514-01	-.107-01	-.362-02	.209-01

CHANNEL NO. 2

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.747+00	-.103+00	-.959-01	-.295+00	-.130+00	.115+00	-.736-01	-.282-01	.195-01	.299-02	.205-01	-.167-01	.633-02	.304-01

CHANNEL NO. 3

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.106+01	-.144+01	.107+00	.224+00	.510-01	-.471-01	-.226-01	.415-01	-.337-01	.522-02	.209-01	.215-02	.322-01	-.290-01

CHANNEL NO. 4

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.565-01	.167+01	-.840-01	-.112+00	.131+00	.321-01	.169+00	-.137-01	.200-01	.735-02	-.298-01	-.854-02	-.324-01	-.101-01

CHANNEL NO. 5

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.195+01	-.166+01	.152+00	.442-01	.322+00	-.361+00	.191+00	.741-01	-.291-01	-.576-02	.728-02	-.100-01	.408-01	-.103+00

CHANNEL NO. 6

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.251+01	.608+01	-.358+00	-.873+00	.675-01	.370+00	.286+00	-.120+00	.118+00	.138-02	-.117+00	-.269-01	-.114+00	.515-01

TABLE 5.4 SMITH POLYNOMIAL COEFFICIENTS AT STP FOR VTPR CHANNELS: H_2O IN THE RANGE 0.5 TO 50 ATM. CM.

POLYNOMIAL COEFFICIENTS

CHANNEL NO.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
1	-.449+00	-.920-01	-.376-02	.111+00	.115+00	-.237+00	-.390+00	-.333-01	.337-03	.746-02	.973-02	-.193-01	.212-01	.764-01
2	-.187+00	.155+01	-.372-01	-.371-01	-.187+00	.236-01	.459+00	-.239-01	-.116-02	.479-02	-.533-02	-.195-01	.930-02	-.466-01
3	.103-01	.225+01	-.398-01	.152+00	-.289+00	.123+00	.845+00	-.395-01	-.218-01	.466-02	.218-04	-.189-02	-.110-01	-.911-01
4	.281+00	.133+00	-.238-01	-.215+00	-.145+00	.287+00	.446+00	.183-01	.147-01	.858-02	-.566-02	-.452-02	-.103-02	-.827-01
5	-.435+00	.146+01	-.434-01	-.808-01	-.788-01	-.230+00	.779-02	-.458-01	.100-01	.406-02	.445-03	-.379-01	.233-01	.337-01
6	-.194+00	.579+00	-.234-01	-.709-01	-.430-01	-.524-01	.581-01	-.177-01	.701-02	.229-02	.150-02	-.192-01	.135-01	.442-02

TABLE 5.5 SMITH POLYNOMIAL COEFFICIENTS AT STP FOR VTPR CHANNELS: O_3 IN THE RANGE 0.005 TO 0.5 ATM. CM.

POLYNOMIAL COEFFICIENTS

CHANNEL NO. 1

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.454-01	-.625+00	-.519-01	-.805-02	-.207+00	.514-01	-.896-01	-.603-02	-.205-01	-.379-03	.823-01	-.240-01	.425-02	.172-01

CHANNEL NO. 2

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.130+01	.284+01	-.228+00	-.462+00	-.366-01	.331+00	.147+00	-.582-01	.668-01	-.496-03	-.150-01	-.459-01	-.772-01	.251-01

CHANNEL NO. 3

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.544-01	.357+01	-.120+00	-.500+00	.478+00	-.183+00	.247+00	.909-02	.441-01	-.316-03	-.109+00	-.422-02	-.413-01	-.436-01

CHANNEL NO. 4

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.187+01	.312+01	-.300+00	-.470+00	-.274+00	.447+00	-.150+00	-.903-01	.645-01	-.300-03	.143-01	-.510-01	-.823-01	.944-01

CHANNEL NO. 5

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
-.142+01	-.260+01	.107+00	.193+00	.752-01	-.340+00	.155-01	.707-01	-.525-01	-.380-03	.666-01	-.866-03	.739-01	-.602-01

CHANNEL NO. 6

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
.134+01	.612+01	-.310+00	-.876+00	.403+00	-.278-01	.352+00	-.309-01	.101+00	-.203-03	-.136+00	-.172-01	-.901-01	-.261-01

Table 5.6. Transmittance deviations for channel 1 at STP using Smith's polynomial model

GAS	ATM.CM	DEVIATION PEAK	MEAN
CO_2	0.005 - 0.5	0.00137	0.000530
	0.5 - 50.0	0.00020	0.000020
H_2O	0.005 - 0.5	0.00022	0.000120
	0.5 - 50.0	0.00324	0.000310
O_3	0.005 - 0.5	0.00001	$\geq$0.000005

Table 5.7. Transmittance deviations for channel 2 at STP using Smith's polynomial model

GAS	ATM.CM	DEVIATION PEAK	MEAN
CO_2	0.005 - 0.5	0.00003	0.00001
	0.50 - 50.0	0.00040	0.00008
H_2O	0.005 - 0.5	0.00059	0.00020
	0.5 - 50.0	0.00066	0.00015
O_3	0.005 - 0.5	0.00229	0.00075

Table 5.8. Transmittance deviations for channel 3 at STP using Smith's polynomial model

GAS	ATM.CM	DEVIATION PEAK	MEAN
CO_2	0.005 - 0.5	0.00002	$\geq$0.000005
	0.5 - 50.0	0.00258	0.00022
H_2O	0.005 - 0.5	0.00034	0.00010
	0.5 - 50.0	0.00316	0.00042
O_3	0.005 - 0.5	0.00084	0.00021

Table 5.9. Transmittance deviations for channel 4 at STP using Smith's polynomial model

GAS	ATM.CM	DEVIATION PEAK	DEVIATION MEAN
CO_2	0.005 - 0.5	0.00002	$\geq$0.000005
	0.5 - 50.0	0.00018	0.00008
H_2O	0.005 - 0.5	0.00020	0.00006
	0.5 - 50.0	0.00205	0.00045
O_3	0.005 - 0.5	0.00010	0.00002

Table 5.10. Transmittance deviations for channel 5 at STP using Smith's polynomial model

GAS	ATM.CM	DEVIATION PEAK	DEVIATION MEAN
CO_2	0.005 - 0.5	0.00002	$\geq$0.000005
	0.5 - 50.0	0.00159	0.00040
H_2O	0.005 - 0.5	0.00191	0.00060
	0.5 - 50.0	0.00015	0.00009
O_3	0.005 - 0.5	0.00020	0.00005

Table 5.11. Transmittance deviations for channel 6 at STP using Smith's polynomial model

GAS	ATM.CM	DEVIATION PEAK	DEVIATION MEAN
CO_2	0.005 - 0.5	0.00001	$\geq$0.000005
	0.5 - 50.0	0.00236	0.00077
H_2O	0.005 - 0.5	0.00055	0.00018
	0.5 - 50.0	0.00024	0.00012
O_3	0.005 - 0.5	0.00001	$\geq$0.000005

Table 5.12 Absolute transmittance deviations of Smith model from original data using Transmittance-Product and Curtis-Godson methods.

Absolute Transmittance Deviations

CO_2 FREQUENCY (CM^{-1})	MEAN CURTIS-GODSON	MEAN TRANS-MITTANCE PRODUCT	PEAK CURTIS-GODSON	PEAK TRANS-MITTANCE PRODUCT
667	0.0018	0.0016	0.0066	0.0069
677	0.0014	0.0012	0.0053	0.0045
694	0.0006	0.0002	0.0027	0.0009
708	0.0010	0.0003	0.0081	0.0014
725	0.0014	0.0006	0.0045	0.0010
747	0.0007	0.0002	0.0046	0.0010
AVERAGE DEVIATION	0.0011	0.0004	0.0053	0.0027

TABLE 5.13. SMITH POLYNOMIAL COEFFICIENT FOR SLANT-PATH CALCULATIONS USING THE TRANSMITTANCE PRODUCT METHOD

CO_2 FREQUENCY (cm^{-1})	Spectral Polynomial Coefficients													
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
667	0.5929+01	0.5357+02	0.3818+00	-0.1489+03	0.4480+01	0.6846+02	0.1337+02	-0.8134+01	-0.2795+02	-0.1932+03	0.1979+02	0.2760+02	-0.2407+02	0.1114+02
677	0.8413+01	0.1712+02	-0.1917+01	0.8154+02	-0.8162+01	-0.1493+03	0.1190+03	-0.9235+03	0.2578+02	0.5819+02	-0.1030+03	-0.3094+02	0.6642+02	-0.3231+01
696	0.1164+01	0.3640+01	0.6791+00	0.1275+02	-0.6305+01	-0.6750+02	-0.1330+01	-0.7453+02	0.5239+01	0.3042+02	-0.3358+01	0.9576+01	0.4005+01	-0.2520+01
708	0.1590+02	0.5003+02	-0.3652+01	0.3113+00	-0.4635+01	0.1594+03	0.1372+03	-0.7286+03	-0.1622+01	-0.2486+03	-0.9750+02	-0.3957+02	0.4674+02	0.1785+02
725	0.2600+01	-0.1951+01	0.9906+00	0.2684+02	0.4594+00	-0.1189+03	-0.4792+00	-0.6038+02	0.6458+01	0.7566+02	-0.7599+02	-0.4126+02	-0.1519+01	-0.4339+01
747	0.5996+01	0.1312+02	0.1027+00	-0.3992+02	0.1104+01	0.1835+03	0.2387+02	0.7415+01	-0.1408+02	-0.9837+02	-0.1825+03	-0.2778+02	-0.8149+01	0.7104+01

6. APPLICATION TO 15μm CO_2: INHOMOGENEOUS PATHS

Previous sections have included discussions of homogeneous-path models for calculating the mean transmittance over a band. For the application of such models to the VTPR experiment it is necessary to have a means for conversion to the inhomogeneous-path cases. Section 3 covered the theory of such methods, and in this section some applications are discussed and evaluated.

6.1 Transmittance Data

The data used in connection with the development of models for inhomogeneous paths consisted of 100 transmittance values corresponding to line-by-line calculations for paths from the satellite height to 100 pressure levels. The U.S. American Standard Atmosphere was used in the calculations. The data was computed by NOAA and supplied by the Atmospheric Science Laboratory at White Sands Missile Range. Only the CO_2 absorber data for the six VTPR Channels were made available for model developments. The gas amounts were computed using equations which were suitable to the particular method applied in the conversion technique.

6.2 Development of Curtis-Godson Method

Band models for homogeneous paths may be used for slant-paths if the variables u, P, T are replaced with equivalent variables. One of those equivalence relations that are available is the one provided by the Curtis-Godson relations discussed in Section 3.3. The form of these equations that were used for the absorber amount is obtained

from equations (3.2) and (3.8) as

$$u'_{i-1} = \frac{1}{S_i} \int S(z)\, du(z) \qquad (3.8)$$

$$u_i = u'_{i-1} + \Delta u_i \qquad (3.2)$$

which for a layered atmosphere become

$$u_i = \frac{1}{S_i} \sum_{n=1}^{i} S_n \Delta u_n \qquad (6.1)$$

For the equivalent pressure (3.9) and (3.10), that is

$$\alpha'_i = \frac{1}{S_i\, u'_{i-1}} \int S(z)\, d(z)\, du(z) \qquad (3.9)$$

$$\alpha'_i = \left(\frac{P'_i}{P_o}\right) \left(\frac{T_o}{T_i}\right)^{1/2} \qquad (3.10)$$

lead to

$$P'_i = \frac{1}{S_i u_i} \sum_{n=1}^{i} S_n\, P_n\, T_n^{-1/2}\, \Delta u_n \qquad (6.2)$$

The band model of Smith was then developed using the slant path transmittances to the 100 levels, together with the equivalent-homogeneous variables u_i, P'_i and T_i. The identity of the homogeneous-path and inhomogeneous-path transmittances was established in (3.11).

Program EIGGAM was written for the model development using (6.1) and (6.2). This program is essentially the earlier presented program EIGGAM 2, but modified to account for the calculation of the equivalent quantities required by the inhomogeneous-path transmittance data. Both programs appear in the Appendix to this report. The results of the calculations are presented in Table 5.12. Appendix D contains the transmittance data used for the inhomogeneous-path model development.

6.3 Development of Transmittance-Product Method

In addition to the method of Curtis and Godson, three other methods were discussed in Section 3, namely: the methods of Weireb and Nuendorffer, of McMillin and Fleming and of transmittance product. For use in connection with band models of the polynomial type the method of Weinreb and Neuendorffer is difficult to apply. This is based on the requirement of the extraction of the gas amount from the avalytical expression for an existing homogeneous-path band model. In the case of polynomials, this involves the numerical solution for the root of a trancedental equation at each pressure level along the path. In addition to this limitation, the band model must be derived from homogeneous-path transmittance data for condition approximating those found along the inhomogeneous paths. That is, line-by-line transmittances for the inhomogeneous paths are never used in the development of the band model. On the other hand, the method of McMillin and Fleming is restricted to uniformly-mixed absorbers and the homogeneous-path band model needs to be developed for each pressure level. This involves an enormous number of spectral parameters in order to cover the entire atmosphere for all absorbers and all channels.

The method of transmittance product was discussed in Sub-section 3.5 and consists of the development of a band model for the incremental transmittances through the layers. These transmittances are given by the ratios $\tau(P_i, T_i, u_i) / \tau(P_{i-1}, T_{i-1}, u_{i-1})$, as given by 3.19 in the form

$$\frac{\tau(P_i, T_i, u_i)}{\tau(P_{i-1}, T_{i-1}, u_{i-1})} = \Delta\tau(P_i, T_i, \Delta u_i) \qquad (3.19)$$

For $\Delta\tau$ the model of Smith was used, with $\Delta\tau$ replacing the transmittance τ. Note that this method avoids the use of equivalent quantities, and uses the inhomogeneous-path transmittances in its development.

Program EIGGAM was modified to develop (3.17) and compare the results with those obtained from the use of the Curtis-Godson procedures. The mean and peak transmittance deviations are presented in Table 5.12 for the six VTPR channels. The model parameters are tabulated in Table 5.13.

7. DISCUSSION AND CONCLUSIONS

The principal goals of the portion of the contractual work reported here was to: a. analyze several types of promising band models for homogenous paths and select the one most useful for the application to the VTPR instrumentation, b. analyze several types of promising methods for applying the homogeneous-path model to inhomogeneous paths and select the most adaptable to part a. above.

Band models of the polynomial type were selected since it is possible to improve on their accuracy by the addition of terms, and they can be developed by linear least-squares procedures. The polynomials proposed by Pierluissi and by Smith were chosen for the analysis. Both of them were subjected to the same input conditions of data, computer methods and the same feasibility analysis. Since the polynomial of Pierluissi includes as special cases a wide variety of models, the conclusions derived in this section also apply to those ramifications.

The polynomial of Pierluissi from a conceptual point of view is broader in applicability and of greater physical validity than perhaps any other general band model in existence. It has been shown in the lierature [6] to apply to high resolution data with high accuracy. With the use of King's model [3] for strong-line absorptance it is applicalbe to gases having absorption lines with spectral distribution ranging from random to regular. With the proper selection of the spectral band parameters it may be used to generate most of the classical models as well as their limiting weak-and strong-line approxi-

mations. This model had been derived earlier, and rederived here with little change for the purpose of documentation as well as for incorporating computational modifications. The computer program to be used for the development of the model has been called EIKCIM and it appears in the Appendix. The developments presented in this report are limited and are incorporated only to help the user in understanding the model. From a practical point of view the model is restricted by the inclusion of the strong-line function which consists of an incomplete gamma function. This function is nonlinear in the spectral parameters and, consequently, the developmental procedures involve the linearization of the least-squares equation. It is necessary to iterate in these procedures to arrive at an optimal set of parameters from an original guess. In general, this part of the procedures is time consuming for the user and wasteful of computer time. A second limitation worthy of criticism is the fact that the model variables (i. e. absorber amount, presure and temperature) appear in the weak-and strong-line function rather than separated, as in Smith's model. This forces the user to go through three developmental procedures, namely: for the weak-line, strong-line and the complete model. It is possible to do away with the first, but not with the second. For these reasons above it was decided upon the recommendation and usage of the model of Smith.

The polynomial model of Smith was programmed as program EIGGAM (See Appendix) and was the model selected for the application to the inhomogeneous path case. The model was developed for CO_2, H_2O in two ranges of gas amounts, and for O_3 in one range. The average transmit-

deviations obtained for the six VTPR channels over all the ranges for CO_2, H_2O and O_3 are, respectively, 0.00036, 0.00047 and 0.00017. Details of these are tabulated in Tables 5.6 through 5.11.

With respect to the methods of conversion for homogeneous paths to actual inhomogeneous atmospheres, the results indicated that the method of transmittance product should be used. This method compared favorably when tested together with the method of Curtis and Godson. An average over all the six VTPR channels for the U.S. Standard 1962 atmospheric profile showed a mean transmittance deviation of 0.0004. This compares favorably with a corresponding value of 0.0011 obtained with the use of the Curtis-Godson equations. Other methods were analyzed in Section 5, but not implemented due both to the scarcity of time and to the fact that they are somewhat impractical or inaccurate. For instance, the method of equivalent mass is only a one-parameter approximation to the Curtis-Godson method. The method of McMillin and Fleming involves 9,000 spectral parameters in order to cover the six channels, the entire atmospheric and the three principal absorbers. Finally, the method of Weinreb and Neuendorffer involves the development of the Smith model for conditions close to those encountered in all the atmospheric layers, as well as the iterative solution for the gas amount at each pressure level. Although the results of the effort reported here include a band model for uniform paths, it was developed for STP conditions. In spite of that, the iterative solution for the absorber amount would be troublesome to obtain because the Smith polynomial is nonlinear in that variable.

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APPENDIX A

PROGRAM EIKCIM

FIVE PARAMETER MODEL FOR HORIZONTAL-PATH TRANSMITTANCE CALCULATIONS

(Equation 4.13)

```
C     PROGRAM EIKCIM
      COMMON/DATA/CAB(19,10)
      DIMENSION UW(100)    ,US(100)    ,TO(100),U(100),     P(100),
     1 TW(100),DTW(100),DTS(100),DTC(100),TS(100),TC(100),T(100)
     2, S(100)
      REAL N,NT,M,K
      CALL DATAST
C
C     INPUT INFORMATION
C
      M=(5.01E-4)*320./330.
      G=980.62
      RHO=1.962E-3
      TO=273.16
      PO=1.01325E+3
      PIP=3.14159265
      TL=2.30258509
      NF=6
      NU=100
      READ(5,1) (U(I),I=1,NU)
    1 FORMAT(10F7.5)
      WRITE(6,1)  (U(I),I=1,NU)
      DO 2 I=1,NU
      P(I)=1.0
      T(I)=1.0
      S(I)=1.0
      UW(I)=U(I)
      US(I)=U(I)
    2 CONTINUE
C
      DO 23 L=1,NF
      READ(5,4)  (TO(I)  ,I=1,NU)
      WRITE(6,4)  (TO(I)  ,I=1,NU)
    4 FORMAT(7F10.8)
C
C
C     TRANSMITTANCE DATA SELECTION
C
C
      NI=0
      DO  8 I=1,NU
      IF(TO(I).LE.0.0000001.OR.TO(I).GT.0.9999999) GO TO 8
      NI=NI+1
      TO(NI)=TO(I)
      UW(NI)=UW(I)
      US(NI)=US(I)
    8 CONTINUE
C
C
C
C     STRONG LINE PARAMETERS N,C
C
C
      NX=0
      B=-2.0
      BT=0.0
```

```
      NT=0.0
      N=0.1
    9 P11=0.0
      P12=0.0
      P22=0.0
      D1=0.0
      D2=0.0
      MF=1
      NX=NX+1
      IF(NX.LE.50) GO TO 12
      GO TO 144
   10 IF(MF.LT.3) GO TO 11
      B=-2.0
      GO TO 144
   11 P11=0.0
      P12=0.0
      P22=0.0
      D1=0.0
      D2=0.0
      B=B-2.0
      MF=MF+1
C
   12 DO 13 I= 1,NI
      CALL ABF(N,B+ALOG(US(I)   )/TL,PABLNF,PABLBF,AB)
      IF(AB.LE.0.0000001) GO TO 13
      X=PABLBF
      Y=PABLNF
      DIF=ALOG(1.-TO(I))/TL-ALOG(AB)/TL
      P11=P11+X**2
      P12=P12+X*Y
      P22=P22+Y**2
      D1=D1+X*DIF
      D2=D2+Y*DIF
   13 CONTINUE
      DET=P11*P22-P12**2
      IF(DET.LE.1.E-28) GO TO 10
      MF=1
      DB=(P22*D1-P12*D2)/DET
      DN=(P11*D2-P12*D1)/DET
      IF(ABS(DB).LE.0.001) GO TO 131
      GO TO 132
  131 IF(ABS(DN).LE.0.001) GO TO 143
      GO TO 132
  132 DTB=ABS(ABS(DB)-ABS(BT))
      DTN=ABS(ABS(DN)-ABS(NT))
      IF(DTB.LE.0.01.AND.DTN.LE.0.01) GO TO 133
      GO TO 134
  133 DB=DB/2.
      DN=DN/2.
  134 IF(DB.GE.0.3) GO TO 135
      GO TO 136
  135 DB=0.3
      GO TO 138
  136 IF(DB.LE.-0.3) GO TO 137
      GO TO 138
  137 DB=-0.3
  138 IF(DN.GE.0.1) GO TO 139
```

```
      GO TO 140
  139 DN=0.1
      GO TO 142
  140 IF(DN.LE.-0.1) GO TO 141
      GO TO 142
  141 DN=-0.1
  142 B=B+DB
      N=N+DN
      BT=DB
      NT=DN
      GO TO 9
  143 B=B+DB
      N=N+DN
  144 IF(N.GE.0.2) GO TO 145
      N=0.2
  145 IF(N.LE.3.5) GO TO 146
      N=3.5
  146 IC=0
      WRITE(6,1431) N,B
 1431 FORMAT(20X,3HN =,F10.5,5X,3HB =,F10.5)
C
      DO 152 KK=1,50
  147 P11=0.0
      D1=0.0
C
      DO 148 I=1,NI
      CALL ABF(N,B+ALOG(US(I)    )/TL,PABLNF,PABLBF,AB)
      X=PABLBF
      P11=P11+X**2
      IF(AB.LE.0.0000001) GO TO 148
      DIF=ALOG(1.-TO(I))/TL-ALOG(AB)/TL
      D1=D1+X*DIF
  148 CONTINUE
      IF(P11.GT.0.0) GO TO 149
      B=B-1.0
      IC=IC+1
      IF(IC.GT.8) GO TO 41
      GO TO 147
  149 DB=D1/P11
      IF(DB.LE.0.5) GO TO 150
      DB=0.5
      GO TO 151
  150 IF(DB.GE.-0.5) GO TO 151
      DB=-0.5
  151 B=B+DB
      IF(ABS(DB).LT.0.0005) GO TO 41
  152 CONTINUE
      B=-2.0
C
C
C     WEAK-LINE PARAMETER.K
C
C
   41 P11=0.0
      D1=0.0
C
      DO 200 I=1,NI
```

```
      WT=1.0
      X=1./UW(I)
      DIF=1./(ALOG(TO(I)    )**2)
      P11=P11+WT*X**4
      D1=D1+WT*DIF*X**2
  200 CONTINUE
C
      DET=P11
      K=SQRT(DET/D1)
C
C
C     QUADRATIC PARAMETERS BW,BS,BWS
C
C
   14 P11=0.0
      P12=0.0
      P13=0.0
      P22=0.0
      P23=0.0
      P33=0.0
      D1 =0.0
      D2 =0.0
      D3=0.0
      NN=0
C
      WRITE(6,1432)N,B,K
 1432 FORMAT(20X,3HN =,F10.5,5X,3HB =,F10.5,5X,3HK =,F10.5)
      DO  16 I=1,NI
      CALL ABF(N,B+ALOG(US(I))/TL,PABLNF,PABLBF,AB)
      IF(AB.LE.0.0000001.OR.AB.GE.1.0000000) GO TO 16
      WT=1.0
      IF (K*UW(I).GE.25.0) GO TO 16
      X=-1./ ALOG(EXP(-K*UW(I)   ))
      Y=-1./ALOG(1.0-AB)
      DIF=1./(ALOG(TO(I)    )**2)
      P11=P11+WT    *(X**4)
      P12=P12+WT    *(X**2)*(Y**2)
      P13=P13+WT    *(X**3)*Y
      P22=P22+WT    *(Y**4)
      P23=P23+WT    *(Y**3)*X
      P33=P33+WT    *(X**2)*(Y**2)
      D1=D1+WT    *DIF*X**2
      D2=D2+WT    *DIF*Y**2
      D3=D3+WT    *DIF*X*Y
   16 CONTINUE
C
      DET=P11*(P22*P33-P23*P23)-P12*(P12*P33-P23*P13)+P13*(P12*P23-P22*P
     113)
       BW=     (D1*(P22*P33-P23*P23)+D2*(P23*P13-P12*P33)+D3*(P12*P23-P22
     1*P13))/DET
       BS=     (D1*(P13*P23-P12*P33)+D2*(P11*P33-P13*P13)+D3*(P13*P12-P11
     1*P23))/DET
       BWS=    (D1*(P12*P23-P22*P13)+D2*(P12*P13-P11*P23)+D3*(P11*P22-P1
     12*P12))/DET
      GO TO 173
  171 DET=P11*P22-P12*P12
      BW=(D1*P22-D2*P12)/DET
```

```
      BS=(D2*P11-D1*P12)/DET
      BWS=0.0
      NN=NN+1
      IF(NN.LT.2) GO TO 173
  172 DET=P11
      BW=D1/DET
      BS=0.0
      BWS=0.0
C
C
C     TRANSMITTANCE TABLE
C
C
  173 AVES=0.0
      AVEC=0.0
      AVEW=0.0
      PEAKS=0.0
      PEAKC=0.0
      PEAKW=0.0
C
      C=EXP(B*TL)
      DO 17 I=1,NU
      CALL ABF(N,B+ALOG(US(I))/TL,PABLNF,PABLBF,AB)
      IF(AB.LE.0.0000001) AB=0.0000001
      TS(I)=1.-AB
      TW(I)=EXP(-K*UW(I)   )
      X=1./(K*UW(I))
      Y=-1./ALOG(TS(I))
      EX=BW*X**2+BS*Y**2+BWS*X*Y
      IF(EX.LE.0.0) GO TO 171
      TC(I)=EXP(-(1./SQRT(EX)))
      DTC(I)=TC(I)-TO(I)
      DTS(I)=TS(I)-TO(I)
      DTW(I)=TW(I)-TO(I)
      XNU=NI
      AVES=AVES+ABS(DTS(I))/XNU
      AVEC=AVEC+ABS(DTC(I))/XNU
      AVEW=AVEW+ABS(DTW(I))/XNU
      IF(ABS(DTS(I)).GE.PEAKS) PEAKS=ABS(DTS(I))
      IF(ABS(DTC(I)).GE.PEAKC) PEAKC=ABS(DTC(I))
      IF(ABS(DTW(I)).GE.PEAKW) PEAKW=ABS(DTW(I))
   17 CONTINUE
      PRINT 20,L    ,N,C,BW,BS,BWS,K
   20 FORMAT(1H1,34X,12HWAVENUMBER =,I7   ,/,31X,16HTEMPERATURE = TO,/,10
     1X,22HSTRONG LINE PARAMETERS,12X,20HQUADRATIC PARAMETERS,25X,19HWEA
     2K LINE PARAMETER,/,11X,3HN =,F8.5,2X,3HC =,E10.5,2X,4HBW =,E10.5,
     3 2X,4HBS =,E10.5,2X,5HBWS =,E10.5,2X,3HK =,E10.5,//,2X,5HLEVEL,5X,
     4 15HMODEL VARIABLES,18X,39HCARBON DIOXIDE SATELLITE TRANSMITTANCES
     5,/,3X,3HNO.,3X,9HWEAK LINE,2X,11HSTRONG LINE,7X,8HORIGINAL,2X,11HS
     6TRONG LINE,2X,9HDEVIATION,2X,10HCALCULATED,2X,9HDEVIATION,2X,9HWEA
     7K LINE,2X,9HDEVIATION,/)
      WRITE(6,21)(I,UW(I)   ,  US(I)   ,TO(I)   ,TS(I),DTS(I),TC(I),
     1 DTC(I),TW(I),DTW(I),I=1,NU)
   21 FORMAT(3X,I3,2X,F9.5,3X,F9.5,9X,F6.4,7X,F6.4,5X,F7.4,6X,F6.4,4X,F7
     1.4,6X,F6.4,4X,F7.4)
      PRINT 22,PEAKC,PEAKS,PEAKW,AVEC,AVES,AVEW
   22 FORMAT(//,5X,10HPOLYNOMIAL,11X,11HSTRONG LINE,15X,9HWEAK LINE,/,5X
```

```
     1,13HMAXIMUM ERROR,F8.4, 3X,13HMAXIMUM ERROR,F8.4,5X,13HMAXIMUM ERR
     2OR,F8.4,/,5X,13HAVE.ABS.ERROR,F8.4,3X,13HAVE.ABS.ERROR,F8.4,3X,13H
     3AVE.ABS.ERROR,F8.4,//)
  23 CONTINUE
     STOP
     END

COMPILATION:          NO  DIAGNOSTICS.
```

```
      SUBROUTINE ABF(N,X,PABLNF,PABLBF,AB)
      COMMON/DATA/CAB(19,10)
      REAL N
      IF(X.GE.2.0.AND.N.GE.2.00) I=19
      IF(X.GE.2.0.AND.N.LT.2.00) I=18
      IF(X.LT.2.0.AND.N.GE.2.00) I=17
      IF(X.LT.2.0.AND.N.LT.2.00) I=16
      IF(X.LT.2.0.AND.N.LT.1.25) I=15
      IF(X.LT.1.5.AND.N.LT.1.25) I=14
      IF(X.LT.1.0.AND.N.GE.2.00) I=13
      IF(X.LT.1.0.AND.N.LT.2.00) I=12
      IF(X.LT.1.0.AND.N.LT.1.25) I=11
      IF(X.LT.0.5.AND.N.LT.1.25) I=10
      IF(X.LT.0.0.AND.N.GE.2.00) I=9
      IF(X.LT.0.0.AND.N.LT.2.00) I=8
      IF(X.LT.0.0.AND.N.LT.1.25) I=7
      IF(X.LT.-1..AND.N.GE.2.00) I=6
      IF(X.LT.-1..AND.N.LT.2.00) I=5
      IF(X.LT.-1..AND.N.LT.1.25) I=4
      IF(X.LT.-2..AND.N.GE.2.00) I=3
      IF(X.LT.-2..AND.N.LT.2.00) I=2
      IF(X.LT.-2..AND.N.LT.1.25) I=1
      TM1=2.*CAB(I,8)*N+2.*CAB(I,4)
      TM2=CAB(I,2)+CAB(I,5)*N+CAB(I,9)*N*N
      DIF=TM1**2-12.*CAB(I,7)*TM2
      IF(DIF.LT.0.0) GO TO 1
      XM1=(-TM1+SQRT(DIF))/(6.*CAB(I,7))
      XM2=(-TM1-SQRT(DIF))/(6.*CAB(I,7))
      GO TO 105
    1 XM1=-100.
      XM2= 100.0
  105 X2=X*X
      ABLF=CAB(I,1)+(CAB(I,2)+(CAB(I,5)+CAB(I,9)*N)*N)*X+(CAB(I,4)+CAB(I
     1,7)*X)*X2+(CAB(I,3)+CAB(I,8)*X2)*N+(CAB(I,6)+CAB(I,10)*N)*N*N
      N2=2.*N
      PABLNF=CAB(I,3)+(CAB(I,5)+CAB(I,8)*X)*X+(CAB(I,10)*1.5*N+CAB(I,6)+
     1CAB(I,9)*X)*N2
      X2=2.*X
      PABLBF=CAB(I,2)+(CAB(I,5)+CAB(I,9)*N)*N+(CAB(I,7)*1.5*X+CAB(I,4)+C
     1AB(I,8)*N)*X2
      IF(ABLF.GT.0.0.OR.X.GE.XM2) GO TO 206
      AB =10.**ABLF
      IF(AB.LE.0.00001) AB=0.00001
      IF(AB.GE.0.99999) AB=0.99999
      RETURN
  206 AB=0.99999
      PABLNF=0.0
      PABLBF=0.0
      RETURN
      END
```

COMPILATION: NO DIAGNOSTICS.

```
      SUBROUTINE DATAST
      COMMON/DATA/CAB(19,10)
      DATA  (CAB( 1,I),I=1,10)/-0.10049677,  .49369689,-0.01667595,
     *-0.00572280,-0.03523860,-0.06165218,-0.00111350,-0.00829432,
     *-0.01891186,-0.00991368/
      DATA  (CAB( 2,I),I=1,10)/-0.09260559,  .47695056,-0.07057190,
     *-0.01700861,-0.06470795,-0.05897522,-0.00197060,-0.00580263,
     *-0.00070225,  .00574112/
      DATA  (CAB( 3,I),I=1,10)/-0.09001160,  .44399718,-0.11988831,
     *-0.02340413,-0.05279564,-0.02771187,-0.00157742,-0.00094148,
     *  .00387880,  .00313902/
      DATA  (CAB( 4,I),I=1,10)/-0.09447873, .48399989, -0.05485392,
     *-0.02835365,-0.11644988,-0.11657858,-0.00674617,-0.02107077,
     *-0.00463960, .02014971/
      DATA  (CAB( 5,I),I=1,10)/-0.08712006, .44202923, -0.12561798,
     *-0.04489990,-0.09403446,-0.04566956,-0.00508810,-0.00083108,
     *0.01405107, .00938129/
      DATA  (CAB( 6,I),I=1,10)/-0.08434296,  .40194668,-0.15971947,
     *-0.04137856,-0.05049891,-0.01260090,-0.00265082,  .00303097,
     *  .00645553,  .00201237/
      DATA  (CAB( 7,I),I=1,10)/-0.08602101,  .43828721,-0.12986088,
     *-0.10501547,-0.17462121,-0.07202101,-0.02307045,  .01511240,
     *  .06046459,  .02769244/
      DATA  (CAB( 8,I),I=1,10)/-0.08036613,  .38655830,-0.17057037,
     *-0.08319844,-0.07112410,-0.01244736,-0.00838463,  .01664010,
     *  .01697508,  .00345602/
      DATA  (CAB( 9,I),I=1,10)/-0.07889557,  .35503306,-0.18284225,
     *-0.05886738,-0.02869178,-0.00037527,-0.00346908,  .00846328,
     *  .00441822,  .00033039/
      DATA  (CAB(10,I),I=1,10)/-0.06808838,  .36149180,-0.19525874,
     *-0.23168556,-0.00920814,-0.00002217,-0.02914264,  .14841503,
     *-0.02421525,  .00330409/
      DATA  (CAB(11,I),I=1,10)/-0.04126403,  .25014116,-0.21722299,
     *-0.27740297,  .29898705,-0.06900251,  .02916168,  .09296339,
     *-0.15389161,  .05155590/
      DATA  (CAB(12,I),I=1,10)/-0.06826305,  .29674162,-0.18988800,
     *-0.13109579,  .04119762,-0.00318336,-0.00720565,  .04444968,
     *-0.01730163,  .00220847/
      DATA  (CAB(13,I),I=1,10)/-0.06970787,  .29306393,-0.19207668,
     *-0.07750695,  .01708052,  .00254536,-0.00361865,  .01521470,
     *-0.00381933,  .00004089/
      DATA  (CAB(14,I),I=1,10)/-0.00690082,  .07486705,-0.12071805,
     *-0.12648489,  .31459381,-0.16937968,  .04418599,-0.11582011,
     *  .06688992,  .00337738/
      DATA  (CAB(15,I),I=1,10)/-3.63675887, 6.84905041,-1.01103686,
     *-4.17934132,  .91541890,  .19824550,  .81422951,-0.11869798,
     *-0.21756210,  .04086180/
      DATA  (CAB(16,I),I=1,10)/-0.03200769,  .17605478,-0.17830563,
     *-0.13592352,  .18703743,-0.05448914,  .01116831,  .01081911,
     *-0.03597160,  .01499814/
      DATA  (CAB(17,I),I=1,10)/-0.05673885,  .22591937,-0.18091726,
     *-0.09560447,  .08087010,-0.01380110,  .00039489,  .01664993,
     *-0.01552738,  .00342301/
      DATA  (CAB(18,I),I=1,10)/-0.02446064,  .05156507,-0.04984835,
     *-0.05230867,  .12797485,-0.08574449,  .00942583,-0.02514555,
     *  .01[illegible]
      [illegible]/-0.030[illegible],  .12980226,-0.1370[illegible],
     *[illegible],-0.0047[illegible],  .00461396,-0.00312041,
```

SAMPLE OUTPUT

WAVENUMBER = 1
TEMPERATURE = 10

STRONG LINE PARAMETERS — N = .79179 C = .44554+01
QUADRATIC PARAMETERS — BW = .32511+03 BS = .13453+01 BWS =-.78536+00
WEAK LINE PARAMETER — K = .69787+01

LEVEL NO.	MODEL VARIABLES WEAK LINE	STRONG LINE	CARBON DIOXIDE SATELLITE TRANSMITTANCES ORIGINAL	STRONG LINE	DEVIATION	CALCULATED	DEVIATION	WEAK LINE	DEVIATION
1	.00500	.00500	.9187	.8841	-.0346	.9268	.0080	.9657	.0470
2	.01000	.01000	.8591	.8336	-.0205	.8632	.0041	.9326	.0735
3	.01500	.01500	.8135	.8046	-.0089	.8141	.0005	.9006	.0871
4	.02000	.02000	.7773	.7768	-.0006	.7757	-.0017	.8697	.0924
5	.02500	.02500	.7476	.7528	.0052	.7447	-.0029	.8399	.0923
6	.03000	.03000	.7224	.7316	.0092	.7190	-.0034	.8111	.0887
7	.03500	.03500	.7006	.7126	.0120	.6970	-.0036	.7833	.0827
8	.04000	.04000	.6812	.6951	.0139	.6777	-.0035	.7564	.0752
9	.04500	.04500	.6639	.6791	.0152	.6605	-.0033	.7305	.0666
10	.05000	.05000	.6481	.6641	.0160	.6450	-.0031	.7054	.0574
11	.05500	.05500	.6335	.6501	.0166	.6308	-.0027	.6812	.0477
12	.06000	.06000	.6201	.6370	.0169	.6177	-.0024	.6579	.0378
13	.06500	.06500	.6075	.6246	.0171	.6055	-.0020	.6353	.0278
14	.07000	.07000	.5957	.6128	.0171	.5942	-.0016	.6135	.0178
15	.07500	.07500	.5847	.6016	.0170	.5834	-.0012	.5925	.0078
16	.08000	.08000	.5742	.5910	.0168	.5733	-.0008	.5722	-.0020
17	.08500	.08500	.5642	.5808	.0166	.5637	-.0005	.5526	-.0117
18	.09000	.09000	.5548	.5710	.0163	.5546	-.0002	.5336	-.0211
19	.09500	.09500	.5457	.5617	.0159	.5459	.0002	.5153	-.0304
20	.10000	.10000	.5371	.5527	.0156	.5376	.0005	.4976	-.0395
21	.10500	.10500	.5288	.5440	.0152	.5296	.0007	.4806	-.0483
22	.11000	.11000	.5209	.5356	.0147	.5219	.0010	.4641	-.0568
23	.11500	.11500	.5133	.5276	.0143	.5145	.0012	.4482	-.0651
24	.12000	.12000	.5060	.5198	.0138	.5074	.0014	.4328	-.0732
25	.12500	.12500	.4989	.5122	.0133	.5005	.0016	.4180	-.0810
26	.13000	.13000	.4921	.5049	.0128	.4939	.0017	.4036	-.0885
27	.13500	.13500	.4855	.4978	.0123	.4874	.0019	.3898	-.0957
28	.14000	.14000	.4792	.4909	.0118	.4812	.0020	.3764	-.1028
29	.14500	.14500	.4730	.4843	.0112	.4751	.0021	.3635	-.1095
30	.15000	.15000	.4671	.4778	.0107	.4692	.0022	.3511	-.1160
31	.15500	.15500	.4613	.4714	.0101	.4635	.0022	.3390	-.1223
32	.16000	.16000	.4557	.4653	.0096	.4579	.0023	.3274	-.1283
33	.16500	.16500	.4502	.4593	.0090	.4525	.0023	.3162	-.1341
34	.17000	.17000	.4449	.4534	.0085	.4472	.0023	.3053	-.1395
35	.17500	.17500	.4398	.4477	.0079	.4421	.0023	.2949	-.1449
36	.18000	.18000	.4348	.4421	.0073	.4371	.0023	.2847	-.1501
37	.18500	.18500	.4299	.4367	.0068	.4321	.0022	.2750	-.1549
38	.19000	.19000	.4252	.4314	.0062	.4273	.0022	.2656	-.1596
39	.19500	.19500	.4205	.4262	.0056	.4227	.0021	.2564	-.1641
40	.20000	.20000	.4160	.4211	.0051	.4181	.0020	.2477	-.1684
41	.20500	.20500	.4116	.4161	.0045	.4136	.0020	.2392	-.1725
42	.21000	.21000	.4073	.4113	.0040	.4092	.0019	.2310	-.1764
43	.21500	.21500	.4031	.4065	.0034	.4049	.0018	.2230	-.1801
44	.22000	.22000	.3990	.4019	.0028	.4007	.0017	.2154	-.1836
45	.22500	.22500	.3950	.3984	.0034	.3978	.0028	.2080	-.1870
46	.23000	.23000	.3911	.3939	.0029	.3937	.0027	.2009	-.1902
47	.23500	.23500	.3872	.3895	.0023	.3898	.0025	.1940	-.1932
48	.24000	.24000	.3835	.3852	.0018	.3859	.0024	.1873	-.1961
49	.24500	.24500	.3798	.3810	.0013	.3821	.0023	.1809	-.1989

50	.25000	.25000	.3762	.3769	.0007	.3783	.0021	.1747	-.2015
51	.25500	.25500	.3726	.3729	.0002	.3746	.0020	.1687	-.2033
52	.26000	.26000	.3692	.3689	-.0003	.3710	.0019	.1629	-.2062
53	.26500	.26500	.3658	.3650	-.0008	.3675	.0017	.1573	-.2084
54	.27000	.27000	.3624	.3612	-.0013	.3640	.0016	.1519	-.2105
55	.27500	.27500	.3592	.3574	-.0018	.3606	.0015	.1467	-.2124
56	.28000	.28000	.3560	.3537	-.0022	.3573	.0013	.1417	-.2142
57	.28500	.28500	.3528	.3501	-.0027	.3540	.0012	.1368	-.2163
58	.29000	.29000	.3497	.3466	-.0031	.3508	.0011	.1321	-.2176
59	.29500	.29500	.3467	.3431	-.0036	.3476	.0009	.1276	-.2190
60	.30000	.30000	.3437	.3396	-.0040	.3445	.0008	.1232	-.2204
61	.30500	.30500	.3407	.3363	-.0045	.3414	.0007	.1190	-.2217
62	.31000	.31000	.3378	.3330	-.0049	.3384	.0005	.1149	-.2229
63	.31500	.31500	.3350	.3297	-.0053	.3354	.0004	.1110	-.2240
64	.32000	.32000	.3322	.3265	-.0057	.3325	.0003	.1072	-.2250
65	.32500	.32500	.3295	.3233	-.0061	.3296	.0001	.1035	-.2260
66	.33000	.33000	.3268	.3202	-.0065	.3268	.0000	.1000	-.2268
67	.33500	.33500	.3241	.3172	-.0069	.3240	-.0001	.0965	-.2275
68	.34000	.34000	.3215	.3142	-.0073	.3213	-.0002	.0932	-.2283
69	.34500	.34500	.3189	.3113	-.0076	.3186	-.0003	.0900	-.2289
70	.35000	.35000	.3164	.3083	-.0080	.3159	-.0005	.0869	-.2294
71	.35500	.35500	.3139	.3055	-.0084	.3133	-.0006	.0840	-.2299
72	.36000	.36000	.3114	.3027	-.0087	.3107	-.0007	.0811	-.2303
73	.36500	.36500	.3090	.2999	-.0091	.3081	-.0008	.0783	-.2307
74	.37000	.37000	.3066	.2972	-.0094	.3056	-.0009	.0756	-.2310
75	.37500	.37500	.3042	.2945	-.0097	.3032	-.0010	.0730	-.2312
76	.38000	.38000	.3019	.2918	-.0100	.3007	-.0011	.0705	-.2314
77	.38500	.38500	.2996	.2892	-.0104	.2983	-.0013	.0681	-.2315
78	.39000	.39000	.2973	.2866	-.0107	.2960	-.0014	.0658	-.2316
79	.39500	.39500	.2951	.2841	-.0110	.2936	-.0015	.0635	-.2316
80	.40000	.40000	.2929	.2816	-.0113	.2913	-.0016	.0613	-.2316
81	.40500	.40500	.2907	.2791	-.0116	.2891	-.0017	.0592	-.2315
82	.41000	.41000	.2886	.2767	-.0118	.2868	-.0018	.0572	-.2314
83	.41500	.41500	.2865	.2743	-.0121	.2846	-.0019	.0552	-.2312
84	.42000	.42000	.2844	.2720	-.0124	.2824	-.0019	.0533	-.2310
85	.42500	.42500	.2823	.2696	-.0127	.2803	-.0020	.0515	-.2308
86	.43000	.43000	.2803	.2673	-.0129	.2781	-.0021	.0497	-.2305
87	.43500	.43500	.2783	.2651	-.0132	.2760	-.0022	.0480	-.2302
88	.44000	.44000	.2763	.2628	-.0134	.2740	-.0023	.0464	-.2299
89	.44500	.44500	.2743	.2606	-.0137	.2719	-.0024	.0448	-.2295
90	.45000	.45000	.2724	.2585	-.0139	.2699	-.0025	.0433	-.2291
91	.45500	.45500	.2705	.2563	-.0141	.2679	-.0025	.0418	-.2287
92	.46000	.46000	.2686	.2542	-.0144	.2660	-.0026	.0403	-.2282
93	.46500	.46500	.2667	.2521	-.0146	.2640	-.0027	.0390	-.2277
94	.47000	.47000	.2648	.2501	-.0148	.2621	-.0028	.0376	-.2272
95	.47500	.47500	.2630	.2480	-.0150	.2602	-.0028	.0363	-.2267
96	.48000	.48000	.2612	.2460	-.0152	.2583	-.0029	.0351	-.2261
97	.48500	.48500	.2594	.2440	-.0154	.2565	-.0030	.0339	-.2255
98	.49000	.49000	.2577	.2421	-.0156	.2547	-.0030	.0327	-.2249
99	.49500	.49500	.2559	.2401	-.0158	.2528	-.0031	.0315	-.2243
100	.50000	.50000	.2542	.2382	-.0160	.2511	-.0031	.0305	-.2237

POLYNOMIAL		STRONG LINE		WEAK LINE	
MAXIMUM ERROR	.0000	MAXIMUM ERROR	.0346	MAXIMUM ERROR	.2316
AVE.ABS.ERROR	.0018	AVE.ABS.ERROR	.0100	AVE.ABS.ERROR	.1646

APPENDIX B

PROGRAM EIGGAM 2

SMITH POLYNOMIAL FOR HORIZONTAL PATHS

(Equation 4.16.)

```
C       PROGRAM EIGGAM 2
        COMMON          TO(100),PO,TO,NU
        DIMENSION C(14),A(14,15),JC(14),IR(14),U(100)
        PO=1.01325E+3
        TO=273.16
        NU=100
        NF=6
C
C                INPUT INFORMATION
C
C
        READ(5,1) (U(I),I=1,NU)
      1 FORMAT(10F7.5)
        WRITE(6,1)  (U(I),I=1,NU)
C
        DO 23 J=1,NF
        READ(5,4) (TO(I),I=1,NU)
        WRITE(6,4) (TO(I),I=1,NU)
      4 FORMAT(7F10.8)
C
```

```
C            POLYNOMIAL COEFFICIENTS
C
      CALL COEFS (U,A)
      WRITE(6,9) ((A(I,L),L=1,15),I=1,14)
    9 FORMAT(2X,15E8.1)
      CALL LSIMEQ(A,14,IR,JC,14,1.0E-20,C,ERR)
      WRITE(6,10) ERR
   10 FORMAT(5X,I5)
      WRITE(6,5) (J,(C(I),I=1,14))
    5 FORMAT(1H1,25X,29HSMITH POLYNOMIAL COEFFICIENTS,//,31X,11HCHANNEL
     1NO.,I3,/,3X,2HC1,7X,2HC2,7X,2HC3,7X,2HC4,7X,2HC5,7X,2HC6,7X,2HC7,
     27X,2HC8,7X,2HC9,7X,3HC10,6X,3HC11,6X,3HC12,6X,3HC13,6X,3HC14,/,
     314E9.3)
C
C            TRANSMITTANCE CALCULATIONS
C
      WRITE(6,6)J
    6 FORMAT(1H1,25X,32HTRANSMITTANCE FOR CARBON DIOXIDE./,36X,11HCHANNE
     1L NO.,I4,/,2X,4HPATH,3X,6HAMOUNT,3X,8HPRESSURE,3X,11HTEMPERATURE,
     211X,13HTRANSMITTANCE,/,3X,3HNO.3X,6HATM.CM,6X,2HMB, 9X,1HK,4X,8HOR
     3IGINAL,2X,10HCALCULATED,2X,9HDEVIATION,/)
C
      SUM=0.0
      DO 8 I=1,NU
      X=ALOG (U(I))
      Y=ALOG(PO)
      Z=ALOG(TO)
      XP=C(1)+C(2)*X+C(3)*Y+C(4)*Z+C(5)*X*Y+C(6)*X*Z+C(7)*X*X+C(8)*X*X*Z
     1+C(9)*Y*Z+C(10)*X**3+C(11)*X*Z*Z+C(12)*Z*Z+C(13)*X*Y*Z+C(14)*X*X*Y
      PX=XP
      IF(XP.LE.-25.0) XP=-25.0
      IF(XP.GT.+25.0) XP=25.0
      XP=EXP(XP)
      IF(XP.LE.-25.0) XP=-25.0
      IF(XP.GT.+25.0) XP=25.0
      TC=EXP(-XP)
      IF(TC.LE.0.00001) TC=0.00000
      IF(TC.GT.0.99999) TC=1.00000
      DT=TC-TO(I)
      SUM=SUM+ABS(DT)
      WRITE(6,7)  I,U(I),PO,TO,TO(I),TC,DT,PX
    7 FORMAT(3X,I3, 1X,F9.4,1X,F8.2,2X,F8.2,3X,F7.5,2X,F7.5,2X,F8.5,
     1  5X,E15.5)
    8 CONTINUE
      AVEDT=SUM/100
      WRITE(6,11) AVEDT
   11 FORMAT(//,8X,19HAVERAGE DEVIATION =,F8.5,//)
   23 CONTINUE
      STOP
      END

COMPILATION:          NO  DIAGNOSTICS.
```

```
      SUBROUTINE COEF3 (U,A)
      COMMON    TO(100),PO,TO,NU
      DIMENSION A(14,15),U(100)
      DO 1 I=1,14
      DO 1 J=1,15
    1 A(I,J)=0.0
C
      DO 2 I=1,NU
      IF(TO(I).LE.0.00001.OR.TO(I).GE.0.99999) GO TO 2
      WT=1.0
      X=ALOG(U(I))
      Y=ALOG(PO)
      Z=ALOG(TO)
      D=ALOG(-ALOG(TO(I)))
      A(1,1)=A(1,1)+1.0*WT
      A(1,2)=A(1,2)+X*WT
      A(1,3)=A(1,3)+Y*WT
      A(1,4)=A(1,4)+Z*WT
      A(1,5)=A(1,5)+X*Y*WT
      A(1,6)=A(1,6)+X*Z*WT
      A(1,7)=A(1,7)+X*X*WT
      A(1,8)=A(1,8)+X*X*Z*WT
      A(1,9)=A(1,9)+Y*Z*WT
      A(1,10)=A(1,10)+X**3*WT
      A(1,11)=A(1,11)+X*Z*Z*WT
      A(1,12)=A(1,12)+Z*Z*WT
      A(1,13)=A(1,13)+X*Y*Z*WT
      A(1,14)=A(1,14)+X*X*Y*WT
      A(1,15)=A(1,15)+D*WT
      A(2,8)=A(2,8)+X**3*Z*WT
      A(2,10)=A(2,10)+X**4*WT
```

```
A(2.11)=A(2.11)+X*X*Z*Z*WT
A(2.13)=A(2.13)+X*X*Y*Z*WT
A(2.14)=A(2.14)+X**3*Y*WT
A(2.15)=A(2.15)+X*D*WT
A(3.3)=A(3.3)+Y*Y*WT
A(3.5)=A(3.5)+X*Y*Y*WT
A(3.9)=A(3.9)+Y*Y*Z*WT
A(3.11)=A(3.11)+X*Y*Z*Z*WT
A(3.12)=A(3.12)+Y*Z*Z*WT
A(3.13)=A(3.13)+X*Y*Y*Z*WT
A(3.14)=A(3.14)+X*X*Y*Y*WT
A(3.15)=A(3.15)+Y*D*WT
A(4.11)=A(4.11)+X*Z**3*WT
A(4.12)=A(4.12)+Z**3*WT
A(4.13)=A(4.13)+X*Y*Z*Z*WT
A(4.14)=A(4.14)+X*X*Y*Z*WT
A(4.15)=A(4.15)+Z*D*WT
A(5.8)=A(5.8)+X**3*Y*Z*WT
A(5.10)=A(5.10)+X**4*Y*WT
A(5.11)=A(5.11)+X*X*Y*Z*Z*WT
A(5.13)=A(5.13)+X*X*Y*Y*Z*WT
A(5.14)=A(5.14)+X**3*Y*Y*WT
A(5.15)=A(5.15)+X*Y*D*WT
A(6.8)=A(6.8)+X**3*Z*Z*WT
A(6.9)=A(6.9)+X*Y*Z*Z*WT
A(6.10)=A(6.10)+X**4*Z*WT
A(6.11)=A(6.11)+X*X*Z**3*WT
A(6.13)=A(6.13)+X*X*Y*Z*Z*WT
A(6.14)=A(6.14)+X**3*Y*Z*WT
A(6.15)=A(6.15)+X*Z*D*WT
A(7.10)=A(7.10)+X**5*WT
A(7.11)=A(7.11)+X**3*Z*Z*WT
A(7.14)=A(7.14)+X**4*Y*WT
A(7.15)=A(7.15)+X*X*D*WT
A(8.8)=A(8.8)+X**4*Z*Z*WT
A(8.10)=A(8.10)+X**5*Z*WT
A(8.11)=A(8.11)+X**3*Z**3*WT
A(8.13)=A(8.13)+X**3*Y*Z*Z*WT
A(8.14)=A(8.14)+X**4*Z*Y*WT
A(8.15)=A(8.15)+X*X*Z*D*WT
A(9.9)=A(9.9)+Y*Y*Z*Z*WT
A(9.11)=A(9.11)+X*Y*Z**3*WT
A(9.12)=A(9.12)+Y*Z**3*WT
A(9.13)=A(9.13)+X*Y*Y*Z*Z*WT
A(9.14)=A(9.14)+X*X*Y*Y*Z*WT
A(9.15)=A(9.15)+Y*Z*D*WT
A(10.10)=A(10.10)+X**6*WT
A(10.11)=A(10.11)+X**4*Z*Z*WT
A(10.14)=A(10.14)+X**5*Y*WT
A(10.15)=A(10.15)+X**3*D*WT
A(11.11)=A(11.11)+X*X*Z**4*WT
A(11.12)=A(11.12)+X*Z**4*WT
A(11.13)=A(11.13)+X*X*Y*Z**3*WT
A(11.14)=A(11.14)+X**3*Y*Z*Z*WT
A(11.15)=A(11.15)+X*Z*Z*D*WT
A(12.12)=A(12.12)+Z**4*WT
A(12.13)=A(12.13)+X*Y*Z**3*WT
```

```
      A(12,14)=A(12,14)+X*X*Y*Z*Z*WT
      A(12,15)=A(12,15)+Z*Z*D*WT
      A(13,13)=A(13,13)+X*X*Y*Y*Z*Z*WT
      A(13,14)=A(13,14)+X**3*Y*Y*Z*WT
      A(13,15)=A(13,15)+X*Y*Z*D*WT
      A(14,14)=A(14,14)+X**4*Y*Y*WT
      A(14,15)=A(14,15)+X*X*Y*D*WT
    2 CONTINUE
      A(2,2)=A(1,7)
      A(2,3)=A(1,5)
      A(2,4)=A(1,6)
      A(2,5)=A(1,14)
      A(2,6)=A(1,8)
      A(2,7)=A(1,10)
      A(2,9)=A(1,13)
      A(2,12)=A(1,11)
      A(3,4)=A(1,9)
      A(3,6)=A(1,13)
      A(3,7)=A(1,14)
      A(3,8)=A(2,13)
      A(3,10)=A(2,14)
      A(4,4)=A(1,12)
      A(4,5)=A(1,13)
      A(4,6)=A(1,11)
      A(4,7)=A(1,8)
      A(4,8)=A(2,11)
      A(4,9)=A(3,12)
      A(4,10)=A(2,8)
      A(5,5)=A(3,14)
      A(5,6)=A(2,13)
      A(5,7)=A(2,14)
      A(5,9)=A(3,13)
      A(5,12)=A(4,13)
      A(6,6)=A(2,11)
      A(6,7)=A(2,8)
      A(6,12)=A(4,11)
      A(7,7)=A(2,10)
      A(7,8)=A(6,10)
      A(7,9)=A(2,13)
      A(7,12)=A(2,11)
      A(7,13)=A(5,8)
      A(8,9)=A(6,13)
      A(8,12)=A(6,11)
      A(9,10)=A(6,14)
      A(10,12)=A(7,11)
      A(10,13)=A(8,14)
      DO 3 I=1,14
      DO 3 J=1,14
    3 A(J,I)=A(I,J)
      RETURN
      END

COMPILATION:          NO DIAGNOSTICS.
```

SAMPLE OUTPUT

TRANSMITTANCE FOR CARBON DIOXIDE

CHANNEL NO. 1

PATH NO.	AMOUNT ATM.CM	PRESSURE MB	TEMPERATURE K	TRANSMITTANCE ORIGINAL	CALCULATED	DEVIATION
1	.0050	1013.25	273.16	.91874	.91861	-.00013
2	.0100	1013.25	273.16	.85911	.85845	-.00066
3	.0150	1013.25	273.16	.81354	.81390	.00036
4	.0200	1013.25	273.16	.77735	.77845	.00111
5	.0250	1013.25	273.16	.74760	.74897	.00137
6	.0300	1013.25	273.16	.72242	.72370	.00128
7	.0350	1013.25	273.16	.70057	.70157	.00100
8	.0400	1013.25	273.16	.68125	.68188	.00064
9	.0450	1013.25	273.16	.66388	.66414	.00026
10	.0500	1013.25	273.16	.64807	.64798	-.00009
11	.0550	1013.25	273.16	.63354	.63315	-.00039
12	.0600	1013.25	273.16	.62008	.61944	-.00063
13	.0650	1013.25	273.16	.60752	.60669	-.00083
14	.0700	1013.25	273.16	.59574	.59477	-.00097
15	.0750	1013.25	273.16	.58465	.58358	-.00107
16	.0800	1013.25	273.16	.57417	.57304	-.00113
17	.0850	1013.25	273.16	.56422	.56306	-.00116
18	.0900	1013.25	273.16	.55475	.55360	-.00116
19	.0950	1013.25	273.16	.54573	.54460	-.00113
20	.1000	1013.25	273.16	.53711	.53601	-.00109
21	.1050	1013.25	273.16	.52885	.52781	-.00103
22	.1100	1013.25	273.16	.52092	.51996	-.00097
23	.1150	1013.25	273.16	.51331	.51242	-.00089
24	.1200	1013.25	273.16	.50599	.50518	-.00081
25	.1250	1013.25	273.16	.49893	.49820	-.00072
26	.1300	1013.25	273.16	.49212	.49148	-.00063
27	.1350	1013.25	273.16	.48554	.48500	-.00054
28	.1400	1013.25	273.16	.47918	.47873	-.00045
29	.1450	1013.25	273.16	.47303	.47267	-.00037
30	.1500	1013.25	273.16	.46707	.46679	-.00028
31	.1550	1013.25	273.16	.46129	.46110	-.00019
32	.1600	1013.25	273.16	.45569	.45557	-.00011
33	.1650	1013.25	273.16	.45024	.45021	-.00003
34	.1700	1013.25	273.16	.44495	.44499	.00004
35	.1750	1013.25	273.16	.43980	.43992	.00011
36	.1800	1013.25	273.16	.43480	.43498	.00018
37	.1850	1013.25	273.16	.42992	.43016	.00024
38	.1900	1013.25	273.16	.42517	.42547	.00030
39	.1950	1013.25	273.16	.42054	.42090	.00035
40	.2000	1013.25	273.16	.41603	.41643	.00040
41	.2050	1013.25	273.16	.41162	.41207	.00045
42	.2100	1013.25	273.16	.40732	.40781	.00049
43	.2150	1013.25	273.16	.40311	.40364	.00053
44	.2200	1013.25	273.16	.39901	.39957	.00056
45	.2250	1013.25	273.16	.39499	.39558	.00059
46	.2300	1013.25	273.16	.39107	.39168	.00061
47	.2350	1013.25	273.16	.38722	.38786	.00063
48	.2400	1013.25	273.16	.38346	.38411	.00065
49	.2450	1013.25	273.16	.37978	.38044	.00067
50	.2500	1013.25	273.16	.37617	.37685	.00068
51	.2550	1013.25	273.16	.37263	.37332	.00068
52	.2600	1013.25	273.16	.36917	.36985	.00069

53	.2650	1013.25	273.16	.36577	.36646	.00069
54	.2700	1013.25	273.16	.36243	.36312	.00069
55	.2750	1013.25	273.16	.35916	.35984	.00068
56	.2800	1013.25	273.16	.35595	.35663	.00068
57	.2850	1013.25	273.16	.35280	.35346	.00067
58	.2900	1013.25	273.16	.34970	.35035	.00065
59	.2950	1013.25	273.16	.34666	.34730	.00064
60	.3000	1013.25	273.16	.34367	.34429	.00062
61	.3050	1013.25	273.16	.34073	.34134	.00060
62	.3100	1013.25	273.16	.33784	.33843	.00058
63	.3150	1013.25	273.16	.33500	.33557	.00056
64	.3200	1013.25	273.16	.33221	.33275	.00054
65	.3250	1013.25	273.16	.32946	.32998	.00051
66	.3300	1013.25	273.16	.32676	.32724	.00049
67	.3350	1013.25	273.16	.32410	.32455	.00046
68	.3400	1013.25	273.16	.32146	.32190	.00043
69	.3450	1013.25	273.16	.31890	.31929	.00040
70	.3500	1013.25	273.16	.31636	.31672	.00036
71	.3550	1013.25	273.16	.31385	.31418	.00033
72	.3600	1013.25	273.16	.31139	.31168	.00030
73	.3650	1013.25	273.16	.30896	.30922	.00026
74	.3700	1013.25	273.16	.30656	.30679	.00022
75	.3750	1013.25	273.16	.30420	.30439	.00019
76	.3800	1013.25	273.16	.30188	.30203	.00015
77	.3850	1013.25	273.16	.29958	.29969	.00011
78	.3900	1013.25	273.16	.29732	.29739	.00007
79	.3950	1013.25	273.16	.29509	.29512	.00003
80	.4000	1013.25	273.16	.29288	.29287	-.00001
81	.4050	1013.25	273.16	.29071	.29066	-.00005
82	.4100	1013.25	273.16	.28857	.28848	-.00009
83	.4150	1013.25	273.16	.28645	.28632	-.00013
84	.4200	1013.25	273.16	.28436	.28419	-.00018
85	.4250	1013.25	273.16	.28230	.28208	-.00022
86	.4300	1013.25	273.16	.28026	.28000	-.00026
87	.4350	1013.25	273.16	.27825	.27795	-.00031
88	.4400	1013.25	273.16	.27627	.27592	-.00035
89	.4450	1013.25	273.16	.27431	.27391	-.00039
90	.4500	1013.25	273.16	.27237	.27193	-.00044
91	.4550	1013.25	273.16	.27045	.26997	-.00048
92	.4600	1013.25	273.16	.26856	.26804	-.00052
93	.4650	1013.25	273.16	.26669	.26613	-.00057
94	.4700	1013.25	273.16	.26485	.26424	-.00061
95	.4750	1013.25	273.16	.26302	.26237	-.00066
96	.4800	1013.25	273.16	.26122	.26052	-.00070
97	.4850	1013.25	273.16	.25943	.25869	-.00074
98	.4900	1013.25	273.16	.25767	.25688	-.00079
99	.4950	1013.25	273.16	.25592	.25509	-.00083
100	.5000	1013.25	273.16	.25420	.25332	-.00088

AVERAGE DEVIATION = .00053

TRANSMITTANCE FOR CARBON DIOXIDE

CHANNEL NO. 1

PATH NO.	AMOUNT ATM.CM	PRESSURE MB	TEMPERATURE K	TRANSMITTANCE ORIGINAL	TRANSMITTANCE CALCULATED	TRANSMITTANCE DEVIATION
1	.5000	1013.25	273.16	.25420	.25445	.00025
2	1.0000	1013.25	273.16	.14222	.14157	-.00066
3	1.5000	1013.25	273.16	.08802	.08795	-.00007
4	2.0000	1013.25	273.16	.05746	.05765	.00019
5	2.5000	1013.25	273.16	.03886	.03906	.00020
6	3.0000	1013.25	273.16	.02693	.02706	.00013
7	3.5000	1013.25	273.16	.01900	.01906	.00006
8	4.0000	1013.25	273.16	.01359	.01360	.00001
9	4.5000	1013.25	273.16	.00982	.00980	-.00001
10	5.0000	1013.25	273.16	.00715	.00712	-.00002
11	5.5000	1013.25	273.16	.00524	.00521	-.00003
12	6.0000	1013.25	273.16	.00386	.00384	-.00002
13	6.5000	1013.25	273.16	.00285	.00284	-.00002
14	7.0000	1013.25	273.16	.00212	.00211	-.00001
15	7.5000	1013.25	273.16	.00158	.00157	-.00001
16	8.0000	1013.25	273.16	.00118	.00117	-.00000
17	8.5000	1013.25	273.16	.00088	.00088	-.00000
18	9.0000	1013.25	273.16	.00066	.00066	-.00000
19	9.5000	1013.25	273.16	.00050	.00050	.00000
20	10.0000	1013.25	273.16	.00038	.00038	.00000
21	10.5000	1013.25	273.16	.00028	.00029	.00000
22	11.0000	1013.25	273.16	.00022	.00022	.00000
23	11.5000	1013.25	273.16	.00016	.00016	.00000
24	12.0000	1013.25	273.16	.00012	.00012	.00000
25	12.5000	1013.25	273.16	.00009	.00009	.00000
26	13.0000	1013.25	273.16	.00007	.00007	.00000
27	13.5000	1013.25	273.16	.00005	.00006	.00000
28	14.0000	1013.25	273.16	.00004	.00004	.00000
29	14.5000	1013.25	273.16	.00003	.00003	.00000
30	15.0000	1013.25	273.16	.00002	.00002	-.00000
31	15.5000	1013.25	273.16	.00002	.00002	-.00000
32	16.0000	1013.25	273.16	.00001	.00001	-.00000
33	16.5000	1013.25	273.16	.00001	.00001	-.00000
34	17.0000	1013.25	273.16	.00001	.00000	-.00001
35	17.5000	1013.25	273.16	.00001	.00000	-.00001
36	18.0000	1013.25	273.16	.00001	.00000	-.00001
37	18.5000	1013.25	273.16	.00000	.00000	-.00000
38	19.0000	1013.25	273.16	.00000	.00000	-.00000
39	19.5000	1013.25	273.16	.00000	.00000	-.00000
40	20.0000	1013.25	273.16	.00000	.00000	-.00000
41	20.5000	1013.25	273.16	.00000	.00000	-.00000
42	21.0000	1013.25	273.16	.00000	.00000	-.00000
43	21.5000	1013.25	273.16	.00000	.00000	-.00000
44	22.0000	1013.25	273.16	.00000	.00000	-.00000
45	22.5000	1013.25	273.16	.00000	.00000	-.00000
46	23.0000	1013.25	273.16	.00000	.00000	-.00000
47	23.5000	1013.25	273.16	.00000	.00000	-.00000
48	24.0000	1013.25	273.16	.00000	.00000	-.00000
49	24.5000	1013.25	273.16	.00000	.00000	-.00000
50	25.0000	1013.25	273.16	.00000	.00000	-.00000
51	25.5000	1013.25	273.16	.00000	.00000	-.00000
52	26.0000	1013.25	273.16	.00000	.00000	-.00000

53	26.5000	1013.25	273.16	.00000	.00000	-.00000
54	27.0000	1013.25	273.16	.00000	.00000	-.00000
55	27.5000	1013.25	273.16	.00000	.00000	-.00000
56	28.0000	1013.25	273.16	.00000	.00000	-.00000
57	28.5000	1013.25	273.16	.00000	.00000	-.00000
58	29.0000	1013.25	273.16	.00000	.00000	-.00000
59	29.5000	1013.25	273.16	.00000	.00000	-.00000
60	30.0000	1013.25	273.16	.00000	.00000	-.00000
61	30.5000	1013.25	273.16	.00000	.00000	.00000
62	31.0000	1013.25	273.16	.00000	.00000	.00000
63	31.5000	1013.25	273.16	.00000	.00000	.00000
64	32.0000	1013.25	273.16	.00000	.00000	.00000
65	32.5000	1013.25	273.16	.00000	.00000	.00000
66	33.0000	1013.25	273.16	.00000	.00000	.00000
67	33.5000	1013.25	273.16	.00000	.00000	.00000
68	34.0000	1013.25	273.16	.00000	.00000	.00000
69	34.5000	1013.25	273.16	.00000	.00000	.00000
70	35.0000	1013.25	273.16	.00000	.00000	.00000
71	35.5000	1013.25	273.16	.00000	.00000	.00000
72	36.0000	1013.25	273.16	.00000	.00000	.00000
73	36.5000	1013.25	273.16	.00000	.00000	.00000
74	37.0000	1013.25	273.16	.00000	.00000	.00000
75	37.5000	1013.25	273.16	.00000	.00000	.00000
76	38.0000	1013.25	273.16	.00000	.00000	.00000
77	38.5000	1013.25	273.16	.00000	.00000	.00000
78	39.0000	1013.25	273.16	.00000	.00000	.00000
79	39.5000	1013.25	273.16	.00000	.00000	.00000
80	40.0000	1013.25	273.16	.00000	.00000	.00000
81	40.5000	1013.25	273.16	.00000	.00000	.00000
82	41.0000	1013.25	273.16	.00000	.00000	.00000
83	41.5000	1013.25	273.16	.00000	.00000	.00000
84	42.0000	1013.25	273.16	.00000	.00000	.00000
85	42.5000	1013.25	273.16	.00000	.00000	.00000
86	43.0000	1013.25	273.16	.00000	.00000	.00000
87	43.5000	1013.25	273.16	.00000	.00000	.00000
88	44.0000	1013.25	273.16	.00000	.00000	.00000
89	44.5000	1013.25	273.16	.00000	.00000	.00000
90	45.0000	1013.25	273.16	.00000	.00000	.00000
91	45.5000	1013.25	273.16	.00000	.00000	.00000
92	46.0000	1013.25	273.16	.00000	.00000	.00000
93	46.5000	1013.25	273.16	.00000	.00000	.00000
94	47.0000	1013.25	273.16	.00000	.00000	.00000
95	47.5000	1013.25	273.16	.00000	.00000	.00000
96	48.0000	1013.25	273.16	.00000	.00000	.00000
97	48.5000	1013.25	273.16	.00000	.00000	.00000
98	49.0000	1013.25	273.16	.00000	.00000	.00000
99	49.5000	1013.25	273.16	.00000	.00000	.00000
100	50.0000	1013.25	273.16	.00000	.00000	.00000

AVERAGE DEVIATION = .00407

APPENDIX C

PROGRAM EIGGAM

DEVELOPMENT OF SMITH POLYNOMIAL FOR INHOMOGENEOUS PATHS

```
C      PROGRAM EIGGAM
       COMMON Y(100),Z(100),D(100),NT      ,WT(100)
       DIMENSION C(14),A(14,15),IR(14),JC(14),UW(100),US(100),U(100),
     1 DU(100),SI(100),PI(100),TI(100),S(100),P(100),T(100),TO(100),
     2 X(100)
       REAL M
       P0=1.01325E+3
       T0=273.16
       NU=100
```

```
      NF=6
      M=4.86E-4
      G=980.62
      RHO=1.962E-3
C
C             INPUT INFORMATION
C
      READ(5,1)(PI(I),I=1,NU)
    1 FORMAT(10F7.2)
      WRITE(6,1)(PI(I),I=1,NU)
      READ(5,2)(TI(I),I=1,NU)
      WRITE(6,2)(TI(I),I=1,NU)
    2 FORMAT(10F8.3)
C
      DO 25 J=1,NF
      WRITE(6,222)
  222 FORMAT(1H1)
      READ(5,3)(W,(SI(I),I=1,6))
      WRITE(6,3)(W,(SI(I),I=1,6))
    3 FORMAT(F10.0,6E10.5)
      READ(5,4)(TO(I),I=1,NU)
      WRITE(6,4)(TO(I),I=1,NU)
    4 FORMAT(5F10.7)
C
C
C             ABSORBER AMOUNTS
C
C
      PUS=0.0
      PUTS=0.0
      DO 7  I=1,NU
      IF(I.GT.1) GO TO 5
      T(I)=((TI(I)+210.020)/(T0*2.))**-0.5
      P(I)=(PI(I)+3.07E-4)/(P0*2.)
      DU(I)=(M*(PI(I)-3.07E-4)*1.E+3)/(G*RHO)
      GO TO 6
    5 T(I)=((TI(I)+TI(I-1))/(T0*2.))**-0.5
      P(I)=(PI(I)+PI(I-1))/(P0*2.)
      DU(I)=(M*(PI(I)-PI(I-1))*1.E+3)/(G*RHO)
    6 IF(TI(I).GE.287.5) S(I)=SI(1)
      IF(TI(I).GE.262.5.AND.TI(I).LT.287.5) S(I)=SI(2)
      IF(TI(I).GE.237.5.AND.TI(I).LT.262.5) S(I)=SI(3)
      IF(TI(I).GE.212.5.AND.TI(I).LT.237.5) S(I)=SI(4)
      IF(TI(I).GE.187.5.AND.TI(I).LT.212.5) S(I)=SI(5)
      IF(TI(I).LT.187.5) S(I)=SI(6)
      PUS=PUS+DU(I)*S(I)
      PUTS=PUTS+DU(I)*P(I)*T(I)*S(I)
      UW(I)=PUS/S(I)
      US(I)=PUTS/(S(I)*P(I)*T(I))
    7 CONTINUE
      WRITE(6,2)(P(I),I=1,NU)
      WRITE(6,2)(T(I),I=1,NU)
      WRITE(6,2)(S(I),I=1,NU)
      WRITE(6,8) (UW(I),I=1,NU)
      WRITE(6,8) (US(I),I=1,NU)
      WRITE(6,8) (DU(I),I=1,NU)
    8 FORMAT(10F10.5)
```

```
C
C
C
C                    TRANSMITTANCE DATA SELECTION
C
C
      NT=0
      DO 9  I=1,NU
      IF(TO(I).LT.0.0000001.OR.TO(I).GT.0.9999999) GO TO 9
      NT=NT+1
      UW(NT)=UW(I)
      US(NT)=US(I)
      DU(NT)=DU(I)
      TO(NT)=TO(I)
      WT(NT)=1.0
      Y(NT)=ALOG(P(I))
      Z(NT)=ALOG(T(I))
      D(NT)=ALOG(-ALOG(TO(NT)))
    9 CONTINUE
C
C           POLYNOMIAL  COEFFICIENTS BY WEAK-LINE
C
C
      DO 99 I=1,NT
      U(I)=UW(I)
   99 X(I)=ALOG(U(I))*0.1
      II=0
   10 CALL COEF(A,X)
      WRITE(6,11)((A(I,L),L=1,15),I=1,14)
   11 FORMAT(//,5X,15E8.2)
      CALL LSIMEQ(A,14,IR,JC,14,1.0E-20,C,ERR)
      WRITE(6,12) ERR
   12 FORMAT(5X,I5)
      WRITE(6,13)(J,(C(I),I=1,14))
   13 FORMAT(///,25X,29HSMITH POLYNOMIAL COEFFICIENTS,//,31X,11HCHANNEL
     1NO.,I3,/,2X,2HC1,6X,2HC2,6X,2HC3,6X,2HC4,6X,2HC5,6X,2HC6,6X,2HC7,
     26X,2HC8,6X,2HC9,6X,3HC10,6X,3HC11,6X,3HC12,6X,3HC13,6X,3HC14,/,
     314E9.4)
C
C           TRANSMITTANCE CALCULATIONS
C
      WRITE(6,14)J
   14 FORMAT(1H1,25X,32HTRANSMITTANCE FOR CARBON DIOXIDE,/,36X,11HCHANNE
     1L NO.,I4,/,2X,4HPATH,3X,6HAMOUNT,3X,8HPRESSURE,3X,11HTEMPERATURE,
     211X,13HTRANSMITTANCE,/,3X,3HNO.,3X,6HATM.CM,6X,2HMB,9X,1HK,4X,8HOR
     3IGINAL,2X,10HCALCULATED,2X,9HDEVIATION,/)
C
      SUM=0.0
      DO 16 I=1,NT
      XP=C(1)+C(2)*X(I)+C(3)*Y(I)+C(4)*Z(I)+C(5)*X(I)*Y(I)+C(6)*X(I)*Z(I
     1)+C(7)*X(I)**2+C(8)*Z(I)*X(I)**2+C(9)*Y(I)*Z(I)+C(10)*X(I)**3+
     2C(11)*X(I)*Z(I)**2+C(12)*Z(I)**2+C(13)*X(I)*Y(I)*Z(I)+C(14)*Y(I)*
     3X(I)**2
      IF(XP.LE.-25.0) XP=-25.0
      IF(XP.GT.+25.0) XP=+25.0
      XP=EXP(XP)
      IF(XP.LE.-25.0) XP=-25.0
```

```
      IF(XP.GT.+25.0) XP=+25.0
      TC=EXP(-XP)
      IF(TC.LE.0.00001) TC=0.00000
      IF(TC.GT.0.99999) TC=1.00000
      DT=TC-TO(I)
      SUM=SUM+ABS(DT)
      WRITE(6,15) I,U(I),P(I),T(I),TO(I),TC,DT
   15 FORMAT(3X,I3,1X,F9.4,1X,F8.2,2X,F8.2,3X,F7.5,2X,F7.5,2X,F8.5)
   16 CONTINUE
      AVEDT=SUM/FLOAT(NT)
      WRITE(6,17) AVEDT
   17 FORMAT(//,8X,19HAVERAGE DEVIATION =,F8.5,//)
      II=II+1
      IF(II.GT.1) GO TO 19
C
C
C             POLYNOMIAL COEFFICIENTS BY STRONG LINE
C
C
      DO 18 I=1,NT
      U(I)=US(I)
   18 X(I)=ALOG(U(I))*0.10
      GO TO 10
   19 CONTINUE
C
C
C             POLYNOMIAL COEFFICIENTS BY TRANSMITTANCE PRODUCT
C
C
      DO 21 I=1,NT
      U(I)=DU(I)
      X(I)=ALOG(U(I))*0.10
      IF(I.GT.1) GO TO 20
      D(I)=ALOG(-ALOG(TO(I)))
      GO TO 21
   20 D(I)=ALOG(-ALOG(TO(I)/TO(I-1)))
   21 CONTINUE
C
      CALL COEF(A,X)
      WRITE(6,11)((A(I,L),L=1,15),I=1,14)
      CALL LSIMEQ(A,14,IR,JC,14,1.0E-20,C,ERR)
      WRITE(6,12)ERR
      WRITE(6,13)(J,(C(I),I=1,14))
C
C             TRANSMITTANCE CALCULATIONS
C
      WRITE(6,14) J
      SUM=0.0
      DO 24 I=1,NT
      XP=C(1)+C(2)*X(I)+C(3)*Y(I)+C(4)*Z(I)+C(5)*X(I)*Y(I)+C(6)*X(I)*Z(
     1I)+C(7)*X(I)**2+C(8)*Z(I)*X(I)**2+C(9)*Y(I)*Z(I)+C(10)*X(I)**3+
     2C(11)*X(I)*Z(I)**2+C(12)*Z(I)**2+C(13)*X(I)*Y(I)*Z(I)+C(14)*Y(I)*
     3X(I)**2
      IF(XP.LE.-25.0) XP=-25.0
      IF(XP.GE.+25.0) XP=+25.0
      XP=EXP(XP)
      IF(XP.LE.-25.0) XP=-25.0
```

```
      IF(XP.GE.+25.0) XP=+25.0
      IF(I.GT.1) GO TO 22
      TC=EXP(-XP)
      GO TO 23
   22 TC=TC*EXP(-XP)
   23 IF(TC.LE.0.00001) TC=0.00000
      IF(TC.GE.0.99999) TC=1.00000
      DT=TC-TO(I)
      SUM=SUM+ABS(DT)
      WRITE(6,15) I,U(I),P(I),T(I),TO(I),TC,DT
   24 CONTINUE
      AVEDT=SUM/FLOAT(NT)
      WRITE(6,17)AVEDT
   25 CONTINUE
      STOP
      END
C
C

COMPILATION:          NO  DIAGNOSTICS.
```

```
      SUBROUTINE COEF(A,X)
      COMMON Y(100),Z(100),D(100),NT,WT(100)
      DIMENSION A(14,15),X(100)
      DO 1 I=1,14
      DO 1 J=1,15
    1 A(I,J)=0.0
C
      DO 2 I=1,NT
      WT(I)=1.0
      A(1,1)=A(1,1)+1.0*WT(I)
      A(1,2)=A(1,2)+X(I)*WT(I)
      A(1,3)=A(1,3)+Y(I)*WT(I)
      A(1,4)=A(1,4)+Z(I)*WT(I)
      A(1,5)=A(1,5)+X(I)*Y(I)*WT(I)
      A(1,6)=A(1,6)+X(I)*Z(I)*WT(I)
      A(1,7)=A(1,7)+X(I)*X(I)*WT(I)
      A(1,8)=A(1,8)+X(I)*X(I)*Z(I)*WT(I)
      A(1,9)=A(1,9)+Y(I)*Z(I)*WT(I)
      A(1,10)=A(1,10)+X(I)**3*WT(I)
      A(1,11)=A(1,11)+X(I)*Z(I)*Z(I)*WT(I)
      A(1,12)=A(1,12)+Z(I)*Z(I)*WT(I)
      A(1,13)=A(1,13)+X(I)*Y(I)*Z(I)*WT(I)
      A(1,14)=A(1,14)+X(I)*X(I)*Y(I)*WT(I)
      A(1,15)=A(1,15)+D(I)*WT(I)
      A(2,8)=A(2,8)+X(I)**3*Z(I)*WT(I)
      A(2,10)=A(2,10)+X(I)**4*WT(I)
      A(2,11)=A(2,11)+X(I)*X(I)*Z(I)*Z(I)*WT(I)
      A(2,13)=A(2,13)+X(I)*X(I)*Y(I)*Z(I)*WT(I)
      A(2,14)=A(2,14)+X(I)**3*Y(I)*WT(I)
      A(2,15)=A(2,15)+X(I)*D(I)*WT(I)
      A(3,3)=A(3,3)+Y(I)*Y(I)*WT(I)
      A(3,5)=A(3,5)+X(I)*Y(I)*Y(I)*WT(I)
      A(3,9)=A(3,9)+Y(I)*Y(I)*Z(I)*WT(I)
```

```
A(3,11)=A(3,11)+X(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(3,12)=A(3,12)+Y(I)*Z(I)*Z(I)*WT(I)
A(3,13)=A(3,13)+X(I)*Y(I)*Y(I)*Z(I)*WT(I)
A(3,14)=A(3,14)+X(I)*X(I)*Y(I)*Y(I)*WT(I)
A(3,15)=A(3,15)+Y(I)*D(I)*WT(I)
A(4,11)=A(4,11)+X(I)*Z(I)**3*WT(I)
A(4,12)=A(4,12)+Z(I)**3*WT(I)
A(4,13)=A(4,13)+X(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(4,14)=A(4,14)+X(I)*X(I)*Y(I)*Z(I)*WT(I)
A(4,15)=A(4,15)+Z(I)*D(I)*WT(I)
A(5,8)=A(5,8)+X(I)**3*Y(I)*Z(I)*WT(I)
A(5,10)=A(5,10)+X(I)**4*Y(I)*WT(I)
A(5,11)=A(5,11)+X(I)*X(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(5,13)=A(5,13)+X(I)*X(I)*Y(I)*Y(I)*Z(I)*WT(I)
A(5,14)=A(5,14)+X(I)**3*Y(I)*Y(I)*WT(I)
A(5,15)=A(5,15)+X(I)*Y(I)*D(I)*WT(I)
A(6,8)=A(6,8)+X(I)**3*Z(I)*Z(I)*WT(I)
A(6,9)=A(6,9)+X(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(6,10)=A(6,10)+X(I)**4*Z(I)*WT(I)
A(6,11)=A(6,11)+X(I)*X(I)*Z(I)**3*WT(I)
A(6,13)=A(6,13)+X(I)*X(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(6,14)=A(6,14)+X(I)**3*Y(I)*Z(I)*WT(I)
A(6,15)=A(6,15)+X(I)*Z(I)*D(I)*WT(I)
A(7,10)=A(7,10)+X(I)**5*WT(I)
A(7,11)=A(7,11)+X(I)**3*Z(I)*Z(I)*WT(I)
A(7,14)=A(7,14)+X(I)**4*Y(I)*WT(I)
A(7,15)=A(7,15)+X(I)*X(I)*D(I)*WT(I)
A(8,8)=A(8,8)+X(I)**4*Z(I)*Z(I)*WT(I)
A(8,10)=A(8,10)+X(I)**5*Z(I)*WT(I)
A(8,11)=A(8,11)+X(I)**3*Z(I)**3*WT(I)
A(8,13)=A(8,13)+X(I)**3*Y(I)*Z(I)*Z(I)*WT(I)
A(8,14)=A(8,14)+X(I)**4*Z(I)*Y(I)*WT(I)
A(8,15)=A(8,15)+X(I)*X(I)*Z(I)*D(I)*WT(I)
A(9,9)=A(9,9)+Y(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(9,11)=A(9,11)+X(I)*Y(I)*Z(I)**3*WT(I)
A(9,12)=A(9,12)+Y(I)*Z(I)**3*WT(I)
A(9,13)=A(9,13)+X(I)*Y(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(9,14)=A(9,14)+X(I)*X(I)*Y(I)*Y(I)*Z(I)*WT(I)
A(9,15)=A(9,15)+Y(I)*Z(I)*D(I)*WT(I)
A(10,10)=A(10,10)+X(I)**6*WT(I)
A(10,11)=A(10,11)+X(I)**4*Z(I)*Z(I)*WT(I)
A(10,14)=A(10,14)+X(I)**5*Y(I)*WT(I)
A(10,15)=A(10,15)+X(I)**3*D(I)*WT(I)
A(11,11)=A(11,11)+X(I)*X(I)*Z(I)**4*WT(I)
A(11,12)=A(11,12)+X(I)*Z(I)**4*WT(I)
A(11,13)=A(11,13)+X(I)*X(I)*Y(I)*Z(I)**3*WT(I)
A(11,14)=A(11,14)+X(I)**3*Y(I)*Z(I)*Z(I)*WT(I)
A(11,15)=A(11,15)+X(I)*Z(I)*Z(I)*D(I)*WT(I)
A(12,12)=A(12,12)+Z(I)**4*WT(I)
A(12,13)=A(12,13)+X(I)*Y(I)*Z(I)**3*WT(I)
A(12,14)=A(12,14)+X(I)*X(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(12,15)=A(12,15)+Z(I)*Z(I)*D(I)*WT(I)
A(13,13)=A(13,13)+X(I)*X(I)*Y(I)*Y(I)*Z(I)*Z(I)*WT(I)
A(13,14)=A(13,14)+X(I)**3*Y(I)*Y(I)*Z(I)*WT(I)
A(13,15)=A(13,15)+X(I)*Y(I)*Z(I)*D(I)*WT(I)
A(14,14)=A(14,14)+X(I)**4*Y(I)*Y(I)*WT(I)
A(14,15)=A(14,15)+X(I)*X(I)*Y(I)*D(I)*WT(I)
```

```
2 CONTINUE
  A(2,2)=A(1,7)
  A(2,3)=A(1,5)
  A(2,4)=A(1,6)
  A(2,5)=A(1,14)
  A(2,6)=A(1,8)
  A(2,7)=A(1,10)
  A(2,9)=A(1,13)
  A(2,12)=A(1,11)
  A(3,4)=A(1,9)
  A(3,6)=A(1,13)
  A(3,7)=A(1,14)
  A(3,8)=A(2,13)
  A(3,10)=A(2,14)
  A(4,4)=A(1,12)
  A(4,5)=A(1,13)
  A(4,6)=A(1,11)
  A(4,7)=A(1,8)
  A(4,8)=A(2,11)
  A(4,9)=A(3,12)
  A(4,10)=A(2,8)
  A(5,5)=A(3,14)
  A(5,6)=A(2,13)
  A(5,7)=A(2,14)
  A(5,9)=A(3,13)
  A(5,12)=A(4,13)
  A(6,6)=A(2,11)
  A(6,7)=A(2,8)
  A(6,12)=A(4,11)
  A(7,7)=A(2,10)
  A(7,8)=A(6,10)
  A(7,9)=A(2,13)
  A(7,12)=A(2,11)
  A(7,13)=A(5,8)
  A(8,9)=A(6,13)
  A(8,12)=A(6,11)
  A(9,10)=A(6,14)
  A(10,12)=A(7,11)
  A(10,13)=A(8,14)
  DO 3 I=1,14
  DO 3 J=1,14
3 A(J,I)=A(I,J)
  RETURN
  END
```

COMPILATION: NO DIAGNOSTICS.

TRANSMITTANCE FOR CARBON DIOXIDE
CHANNEL NO. 1

PATH NO.	AMOUNT ATM.CM	PRESSURE MB	TEMPERATURE K	TRANSMITTANCE ORIGINAL	CALCULATED	DEVIATION
1	.0024	.00	1.18	.99125	.99126	.00000
2	.0051	.00	1.20	.98880	.98880	.00000
3	.0101	.00	1.16	.98553	.98555	.00003
4	.0206	.00	1.11	.98093	.98081	-.00012
5	.0315	.00	1.08	.97542	.97532	-.00010
6	.0492	.00	1.05	.96918	.96946	.00028
7	.0694	.00	1.03	.96178	.96197	.00019
8	.0994	.00	1.02	.95276	.95274	-.00001
9	.1348	.00	1.01	.94168	.94127	-.00041
10	.1777	.00	1.01	.92845	.92815	-.00030
11	.2282	.00	1.00	.91306	.91328	.00022
12	.2914	.00	1.01	.89552	.89560	.00008
13	.3646	.00	1.01	.87594	.87555	-.00039
14	.4390	.00	1.02	.85461	.85425	-.00036
15	.5401	.00	1.03	.83190	.83160	-.00029
16	.6563	.00	1.04	.80828	.80830	.00002
17	.7876	.00	1.04	.78427	.78486	.00059
18	.9367	.00	1.05	.76025	.76150	.00125
19	1.1059	.00	1.06	.73650	.73818	.00168
20	1.2954	.00	1.07	.71314	.71501	.00188
21	1.4601	.01	1.07	.69007	.68941	-.00067
22	1.6950	.01	1.08	.66711	.66740	.00028
23	1.9552	.01	1.09	.64400	.64579	.00179
24	2.2406	.01	1.09	.62045	.62321	.00276
25	2.5539	.01	1.09	.59628	.59839	.00211
26	2.8949	.01	1.10	.57136	.57168	.00032
27	3.2687	.01	1.10	.54571	.54403	-.00168
28	3.6754	.01	1.10	.51939	.51596	-.00342
29	4.1149	.02	1.10	.49248	.48796	-.00452
30	4.5924	.02	1.10	.46512	.46003	-.00509
31	5.1077	.02	1.11	.43745	.43208	-.00537
32	5.6609	.02	1.11	.40961	.40438	-.00522
33	6.2570	.02	1.11	.38177	.37710	-.00466
34	6.8936	.03	1.11	.35409	.35030	-.00380
35	7.5781	.03	1.11	.32676	.32411	-.00265
36	8.3056	.03	1.11	.29992	.29851	-.00141
37	9.0836	.03	1.12	.27374	.27378	.00004
38	9.9122	.04	1.12	.24836	.24999	.00163
39	10.7937	.04	1.12	.22393	.22736	.00343
40	11.7284	.04	1.12	.20057	.20580	.00523
41	12.7186	.05	1.12	.17838	.18492	.00654
42	13.7694	.05	1.12	.15747	.16431	.00685
43	14.8783	.06	1.12	.13788	.14407	.00619
44	16.0504	.06	1.12	.11968	.12463	.00496
45	17.2856	.07	1.12	.10291	.10640	.00349
46	18.5890	.07	1.12	.08760	.08968	.00208
47	19.9581	.08	1.12	.07374	.07463	.00089
48	21.4005	.08	1.12	.06135	.06134	-.00001
49	22.9136	.09	1.12	.05039	.04978	-.00061
50	24.5024	.09	1.12	.04081	.03987	-.00093
51	26.1671	.10	1.12	.03256	.03150	-.00106
52	27.9126	.11	1.12	.02558	.02451	-.00107

53	29.7389	.11	1.12	.01975	.01877	-.00098
54	31.6485	.12	1.12	.01495	.01411	-.00084
55	33.6441	.13	1.12	.01110	.01040	-.00069
56	35.7281	.14	1.12	.00806	.00751	-.00055
57	37.9030	.14	1.12	.00572	.00531	-.00040
58	40.1688	.15	1.12	.00395	.00370	-.00025
59	42.5306	.16	1.12	.00265	.00255	-.00010
60	44.9910	.17	1.12	.00173	.00173	.00000
61	47.5498	.18	1.12	.00109	.00113	.00004
62	50.2123	.19	1.12	.00067	.00070	.00003
63	52.9782	.20	1.12	.00039	.00040	.00001
64	55.8503	.21	1.12	.00021	.00020	-.00000
65	58.8336	.22	1.12	.00009	.00009	-.00001
66	61.9279	.24	1.12	.00002	.00003	.00001

AVERAGE DEVIATION = .00156

APPENDIX D

INPUT DATA FOR INHOMOGENEOUS PATHS FOR STANDAARD ATMOSPHERE (NOAA)

PRESSURE

0.01	0.02	0.04	0.08	0.12	0.19	0.27	0.38	0.52	0.69
0.89	1.14	1.43	1.77	2.17	2.63	3.15	3.74	4.41	5.16
5.99	6.92	7.95	9.08	10.32	11.67	13.15	14.76	16.50	18.39
20.43	22.62	24.98	27.50	30.21	33.09	36.17	39.45	42.94	46.64
50.56	54.72	59.11	63.75	68.64	73.80	79.22	84.93	90.92	97.21
103.80	110.71	117.94	125.50	133.40	141.65	150.26	159.23	168.58	178.32
188.45	198.99	209.94	221.31	233.12	245.37	258.08	271.25	284.89	299.01
313.63	328.75	344.38	360.54	377.23	394.47	412.26	430.62	449.56	469.08
489.20	509.93	531.28	553.27	575.89	599.17	623.11	647.72	673.03	699.03
725.74	753.17	781.34	810.25	839.91	870.35	901.56	933.57	966.38	1000.00

TEMPERATURE

180.650	196.370	212.083	227.731	242.456	254.873	261.553	264.272	267.164	270.404
271.180	269.210	265.122	260.793	256.156	252.171	248.456	244.976	241.696	238.630
235.736	232.878	230.316	228.580	227.465	226.630	225.386	225.131	224.384	223.675
222.993	222.331	221.667	221.060	220.457	219.880	219.314	218.743	218.161	217.617
217.191	216.895	216.735	216.661	216.636	216.637	216.649	216.656	216.658	216.653
216.645	216.636	216.632	216.639	216.662	216.691	216.697	216.655	216.554	216.458
216.455	216.629	217.057	217.777	218.816	220.199	221.943	223.978	226.180	228.425
230.612	232.729	234.791	236.815	238.817	240.812	242.815	244.827	246.344	248.860
250.870	252.869	254.854	256.829	258.792	260.747	262.693	264.633	266.567	268.496
270.418	272.335	274.245	276.148	278.045	279.936	281.820	283.697	285.567	287.421

CHANNEL #1 DATA (667. CM-1)

LINE INTENSITY

0.99567000E 00 0.10246000E 01 0.10579000E 01 0.10958990E 01
0.11386000E 01 0.11852990E 01

TRANSMITTANCE

0.9912522 0.9887992 0.9855257 0.9809312 0.9754219 0.9691829 0.9617841 0.9527576
0.9416825 0.9284465 0.9130590 0.8955176 0.8759431 0.8546092 0.8318965 0.8082847
0.7842697 0.7602461 0.7365001 0.7131353 0.6900716 0.6671118 0.6440011 0.6204542
0.5962752 0.5713562 0.5457108 0.5193850 0.4924806 0.4651205 0.4374461 0.4096073
0.3817680 0.3540947 0.3267568 0.2999204 0.2737381 0.2483594 0.2239301 0.2005684
0.1783822 0.1574659 0.1378793 0.1196765 0.1029083 0.0875955 0.0737431 0.0613506
0.0503860 0.0408055 0.0325631 0.0255790 0.0197456 0.0149543 0.0110964 0.0080577
0.0057176 0.0039548 0.0026536 0.0017254 0.0010905 0.0006691 0.0003877 0.0002057
0.0000937 0.0000221 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000

CHANNEL #2 DATA (677. CM-1)

LINE INTENSITY

0.99553000E 00 0.10263000E 01 0.10644990E 01 0.11111000E 01
0.11670990E 01 0.12327990E 01

TRANSMITTANCE

0.9996573 0.9994263 0.9991040 0.9986178 0.9979771 0.9972068 0.9962509 0.9950477
0.9935374 0.9916724 0.9894102 0.9867107 0.9835282 0.9798033 0.9754646 0.9704375
0.9646457 0.9580113 0.9504560 0.9419014 0.9322697 0.9214837 0.9094689 0.8961537
0.8814695 0.8653548 0.8477610 0.8286457 0.8079812 0.7857549 0.7619757 0.7366637
0.7098893 0.6817043 0.6522094 0.6215207 0.5897962 0.5572026 0.5239108 0.4901240
0.4560576 0.4219230 0.3879599 0.3543727 0.3217389 0.2892205 0.2580749 0.2281577
0.1996655 0.1727913 0.1477255 0.1246094 0.1035442 0.0846296 0.0679629 0.0535567
0.0413202 0.0311564 0.0229495 0.0164860 0.0115209 0.0078094 0.0051144 0.0032407
0.0020065 0.0012304 0.0007364 0.0004220 0.0002372 0.0001327 0.0000656 0.0000223
0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
0.0000000 0.0000000 0.0000000 0.0000000

CHANNEL #3 DATA (694. CM-1)

LINE INTENSITY

0.10297000E 01	0.84701990E 00	0.67179000E 00	0.50659000E 00
0.35562000E 00	0.22473000E 00		

TRANSMITTANCE

0.9998886	0.9997724	0.9995451	0.9992661	0.9988837	0.9983867	0.9977501	0.9969480
0.9959567	0.9947689	0.9933798	0.9917662	0.9899111	0.9877984	0.9853924	0.9826533
0.9795397	0.9760055	0.9720186	0.9675411	0.9625360	0.9569818	0.9508457	0.9440775
0.9366135	0.9283963	0.9193872	0.9095510	0.8988561	0.8872734	0.8747759	0.8613401
0.8469486	0.8315846	0.8152282	0.7978670	0.7795139	0.7601867	0.7399037	0.7186845
0.6965495	0.6735269	0.6496657	0.6250185	0.5996404	0.5736140	0.5470359	0.5200070
0.4926517	0.4651038	0.4374970	0.4099688	0.3826592	0.3557086	0.3292570	0.3034795
0.2783848	0.2542214	0.2310678	0.2089913	0.1880428	0.1682730	0.1497252	0.1324017
0.1162913	0.1013829	0.0876655	0.0751319	0.0637769	0.0535958	0.0445751	0.0366587
0.0297775	0.0238624	0.0188443	0.0146541	0.0112214	0.0084623	0.0062849	0.0045967
0.0033056	0.0023204	0.0015758	0.0010345	0.0006605	0.0004178	0.0002704	0.0001822
0.0001213	0.0000770	0.0000459	0.0000244	0.0000087	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000				

CHANNEL #4 DATA (708. CM-1)

LINE INTENSITY

0.10476990E 01	0.77134000E 00	0.54325000E 00	0.35931990E 00
0.21697000E 00	0.11428990E 00		

TRANSMITTANCE

0.9999184	0.9998127	0.9995949	0.9991881	0.9986458	0.9980549	0.9974198	0.9967394
0.9960124	0.9952376	0.9944133	0.9935343	0.9926020	0.9916141	0.9905476	0.9893779
0.9880878	0.9866604	0.9850912	0.9833726	0.9814930	0.9794706	0.9772836	0.9749153
0.9723356	0.9695191	0.9664537	0.9631294	0.9595366	0.9556663	0.9515090	0.9470566
0.9423026	0.9372393	0.9318528	0.9261302	0.9200672	0.9136612	0.9069078	0.8997913
0.8922913	0.8843875	0.8760601	0.8672891	0.8580555	0.8483452	0.8381473	0.8274517
0.8162561	0.8045603	0.7923661	0.7796727	0.7664821	0.7527954	0.7386142	0.7239489
0.7088211	0.6932527	0.6772609	0.6608384	0.6439697	0.6266393	0.6088248	0.5904661
0.5714906	0.5518257	0.5314028	0.5102051	0.4882525	0.4655656	0.4421822	0.4182241
0.3938391	0.3691747	0.3443787	0.3195986	0.2949835	0.2706982	0.2469167	0.2238133
0.2015622	0.1803357	0.1602497	0.1413604	0.1237210	0.1073848	0.0924050	0.0788350
0.0667105	0.0559760	0.0465459	0.0383345	0.0312560	0.0252249	0.0201514	0.0159399
0.0124942	0.0097184	0.0075162	0.0057917				

CHANNEL #5 DATA (725. CM-1)

LINE INTENSITY

0.10381000E 01	0.80928990E 00	0.60284000E 00	0.42107990E 00
0.26805000E 00	0.14367000E 00		

TRANSMITTANCE

0.9999406	0.9998528	0.9996685	0.9993202	0.9988530	0.9983511	0.9978259	0.9972836
0.9967284	0.9961492	0.9955288	0.9948499	0.9941029	0.9932790	0.9923587	0.9913252
0.9901657	0.9888687	0.9874330	0.9858569	0.9841385	0.9822838	0.9802920	0.9781516
0.9758468	0.9733668	0.9707119	0.9678845	0.9648891	0.9617318	0.9584205	0.9549643
0.9513736	0.9476581	0.9438823	0.9398721	0.9358121	0.9316497	0.9273898	0.9230279
0.9185550	0.9139624	0.9092406	0.9043803	0.8993723	0.8942080	0.8888794	0.8833787
0.8776992	0.8718349	0.8657793	0.8595253	0.8530647	0.8463881	0.8394882	0.8323599
0.8250023	0.8174151	0.8095956	0.8015311	0.7932053	0.7846021	0.7757012	0.7664616
0.7568351	0.7467736	0.7362296	0.7251670	0.7135558	0.7013705	0.6885842	0.6751968
0.6612142	0.6466423	0.6314870	0.6157542	0.5994508	0.5825945	0.5652095	0.5473204
0.5289515	0.5101276	0.4908861	0.4712774	0.4513526	0.4311627	0.4107588	0.3901921
0.3695175	0.3488097	0.3281502	0.3076203	0.2873017	0.2672755	0.2476252	0.2284368
0.2097965	0.1917906	0.1745051	0.1580265				

CHANNEL #6 DATA (747. CM-1)

LINE INTENSITY

0.10580990E 01	0.72225930E 00	0.45428990E 00	0.25615000E 00
0.12422000E 00	0.48553990E-01		

TRANSMITTANCE

0.9999940	0.9999867	0.9999646	0.9999113	0.9998131	0.9996710	0.9994851	0.9992550
0.9989831	0.9986877	0.9983882	0.9980888	0.9977905	0.9974950	0.9971957	0.9968852
0.9965574	0.9962068	0.9958319	0.9954303	0.9949996	0.9945393	0.9940474	0.9935190
0.9929448	0.9923170	0.9916329	0.9908902	0.9900866	0.9892203	0.9882896	0.9872934
0.9862305	0.9850995	0.9838978	0.9826232	0.9812751	0.9798536	0.9783583	0.9767850
0.9751287	0.9733826	0.9715421	0.9696007	0.9675525	0.9653926	0.9631164	0.9607196
0.9581998	0.9555552	0.9527840	0.9498836	0.9468503	0.9436808	0.9403714	0.9369207
0.9333294	0.9295983	0.9257264	0.9217034	0.9175160	0.9131506	0.9085897	0.9037932
0.8987133	0.8933024	0.8875132	0.8813033	0.8746334	0.8674645	0.8597618	0.8515114
0.8427059	0.8333390	0.8234002	0.8128853	0.8017868	0.7901103	0.7778687	0.7650749
0.7517417	0.7378821	0.7235006	0.7086384	0.6932825	0.6774563	0.6611738	0.6444493
0.6273000	0.6097529	0.5918685	0.5736651	0.5551891	0.5364799	0.5175741	0.4985047
0.4793040	0.4600045	0.4406387	0.4212390				